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Here's Another One—

And Some More Evidence of How Long a Good Motor Will Stand Up

SO FAR, the nearest approach to Mr. Winchell's old-timer still in service, that was shown in our last issue on page 461, is the one referred to in this order for parts. L. T. Hemmenway of the Holtzer-Cabot Electric Company, in entering this 18-year-old in the contest for honors on years of service without complaint, has the following to say:

"For your information, this set has been running steady, 23 hours per day on an average, for the past 18 years and this is the first repairs. Some machine."

This refers to one of our Type E, 165-watt, 80-volt, 1,000-r.p.m., separately excited, alternating-current generators, directly connected to a Type 3½, ½-hp., 110-volt, shunt-wound, direct-current motor, which, according to our records, was shipped to this company on September 10, 1903.

We, unfortunately, do not have a picture of this set, but I thought that possibly the enclosed information regarding this remarkable performance might be of interest to you.

It would seem as if this goes Sawyer's five-year-old a whole handful better.

I have been particularly interested in your stories of record-making motors. They have brought to mind an order which we received the early part of this year from the Springfield Xenia Telephone Company for two bearings. I enclose photographic copy of this order and wish to call your attention to the note thereon, reading as follows:

In defense of Sawyer I feel obligated to say that he made no claims for his motor record except that the cost of repairs had been nothing under severe continuous duty in the operation of a brine pump. For that matter, Mr. Winchell, in introducing his 30-year-old, showed a little caution when he said, "I feel sure that someone will dig up a motor older than this one and I will watch for his notice with much interest."

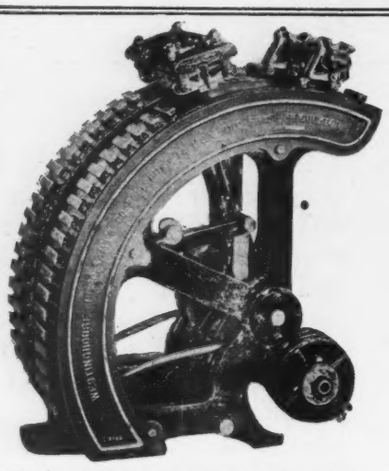
If anyone has felt bashful to date in bringing forth the history of a motor whose age is respected, the respectability of the company he will be associated with has been sufficently established to remove such timidity. In other words, the opportunity is still open to challenge the service of the Winchell 30-year-old, the Hemmenway 18-year-old and the Sawyer 5-year-old. The only restriction is continuous service without repairs and the name of the plant where the holder of the suspected age record is located.

In addition to showing the kind of service first invaded by a motor (because our oldest motors date back practically to the start of things electrical) these records will give some practical information for theorists to theorize some more on motor depreciation.

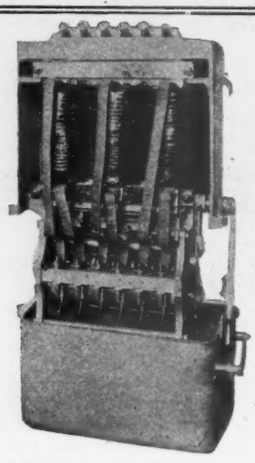
Practical Pete

Alternating-Current Motor Starters

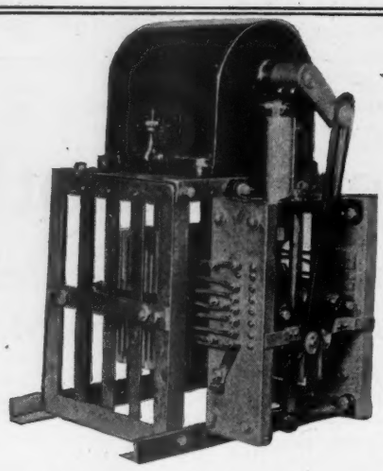
Some Early Designs and Present Day Types



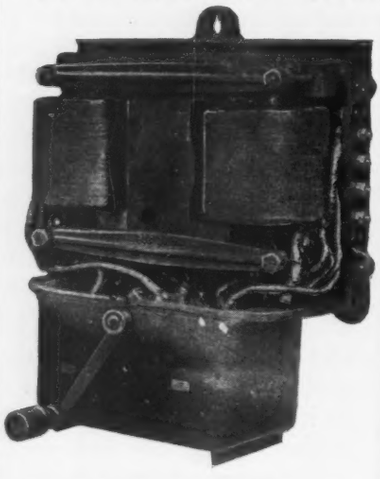
1897-WESTINGHOUSE STARTER AND CONTROLLER
USED WITH PAIR OF AUTO-TRANSFORMERS



1899-GENERAL ELECTRIC
COMPENSATOR



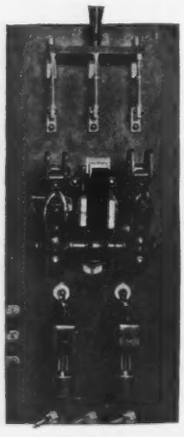
1904-CUTLER-HAMMER SELF STARTER



1905-WAGNER AUTO STARTER

THE FIRST starters for alternating-current motors consisted of resistance which was thrown in series with the motor. About 1893 transformers, usually with several taps, were first employed to reduce the voltage in starting. Probably in 1895 the first auto-transformer was employed in the same way as the present so-called compensator and auto-starter. The Westinghouse and the General Electric Companies started building their manual type of starter about 1898. These starters were the same in principle as the modern starters. The contacts were oil-immersed. In 1904 the Cutler-Hammer Company was putting out self-starters for induction motors. Among the valuable developments in this direction is the automatic, across-the-line starter for small squirrel-cage motors. One of the first starters of this type was made by the Allen-Bradley Company in 1913.

1910--MONITOR
HAS PRE-SET SPEED CONTROLLER



1913-ALLEN-BRADLEY
AUTOMATIC ACROSS-THE-LINE
STARTER FOR SQUIRREL-CAGE MOTORS

1915-CONDIT
FUSED DOUBLE-THROW OIL-IMMERSED SWITCH

1918-ELECTRIC CONTROLLER & MFG. CO
AUTOMATIC COMPENSATOR

Some Examples of

Lighting in Woodworking Plants

By Proper Use of Both General and Localized-General Illumination

By A. D. BELL

Lighting Service Department, Edison Lamp Works of General Electric Company, Harrison, N. J.

ALTHOUGH most sawmills are rough in construction and operate only in the daytime, it is nevertheless sometimes worth while to provide a certain amount of illumination. The most important places to light are the saws and the log travels. If they are well lighted the likelihood of accidents is decreased. The saw may be satisfactorily lighted by a 100-watt bowl-enameled Mazda C lamp in an R. L. M. standard dome reflector for each saw. The reflector should be hung approximately 6 ft. above the saw, in line with and a few inches forward of the center. The log travel should be lighted by a row of similar units down the center of the travel; these units should be hung from 12 to 15 ft. high and spaced approximately 15 ft. apart.

It is when the timber has reached the finishing mill or woodworking plant that the more detailed work is done on it and hence the lighting requirements are more exacting. Often in the smaller plants several operations are carried on in one area and consequently a large variety of machinery is found. In the older plants of this type the ceilings are frequently quite low and are often cluttered up with belting and shafting. Such conditions usually make it necessary to employ what is known as localized general illumination. This, as every one familiar with lighting knows, is a combination of general and local illumination. General illumination consists in having the whole working area evenly illuminated to a sufficiently high intensity to permit work in any part of it, as exemplified in Fig. 1 and in *B*, *C* and *F* of Fig. 2. With local illumination each machine is lighted by an individual lamp and reflector while the remaining area is mostly in darkness.

Localized general illumination is a modification of these systems, and is produced by having the equipment so arranged that the lighting units come directly over the machinery, or nearly so. They are hung sufficiently high to distribute a fairly high intensity about the room; so that the different operations may be successfully carried on there as well, as shown in *A*, *D* and *E* of Fig. 2 and in Fig. 3.

Fig. 1—General illumination applied to a woodworking plant with machines closely spaced.

A 300-watt bowl-enameled Mazda lamp in a large diffusing reflector is used in each bay (16 by 12 ft.). Safety is increased and efficient production made possible through this adequate lighting.

ACTUAL FIGURES on how to light wood-working and other plants will always interest the man responsible for such illumination. He wants to know the positions and sizes of lamps, with the proper spacings, heights, intensities required, and so on. In this article Mr. Bell has given this concrete data, taking up each process through which the wood goes from the tree to the finished article. The out-of-doors operations, starting with felling the tree, are seldom done at night. If they were, flood-lighting or fixtures of the street-lighting type might be employed.

In the more modern plant which has fairly high ceilings and where the machinery is largely motor driven, it is ordinarily feasible to use general illumination. While the different operations usually are carried on in different sections (in contrast to several operations on one floor), yet conditions are often such that the same intensity is not required throughout a whole floor. For example, part of an area may be devoted to machine work while the remainder is used for storage, as in *B* of Fig. 2. Obviously not as much light is needed for storage as for sawing. The problem then is to provide a certain minimum intensity throughout the different areas and to arrange for a higher intensity in those sections where the work carried on is of a more important nature and requires more light for its proper execution.

Whatever scheme of lighting is employed, it is essential that the right kind of reflecting equipment be chosen. For most industrial work R. L. M. standard dome reflectors

Fig. 2—Good illumination in six rooms of woodworking plants.

A—Well applied localized general illumination for sanders. The 100-watt bowl-enameled Mazda C lamps in R. L. M. standard dome reflectors hung 10 ft. high provide an intensity of 6 ft.-candles at the work. *B*—A night view of the cutting room of the Berkey & Gay Furniture Co., Grand Rapids, Mich. R. L. M. standard dome reflectors and 200-watt Mazda C lamps hung from 10 to 15 ft. high on 12-ft. centers furnish an intensity of 7 ft.-candles on the machines. The remainder of the room, which is devoted to storage, has one similar unit per bay. *C*—Work may be easily performed at night in this filling room of a furniture factory. There are three rows of 20-ft. bays. The center storage aisle has one lighting unit per bay consisting of an R. L. M. standard dome reflector and a 200-watt Mazda C lamp, while the working areas have two such units per bay, providing respectively 3 and 5 ft.-candles. *D*—The boring machines shown here are lighted by a localized system of general illumination consisting of 100-watt bowl-enameled Mazda C lamps in R. L. M. standard dome reflectors, hung 10 ft. high. The intensity is only 3 ft.-candles on the machines, yet the lighting is so well arranged that it is quite sufficient with the light-colored woods which are handled. *E*—The rip band saw shown in this night photograph can be as easily operated by night as by day. The well-spaced 100-watt bowl-enameled Mazda C lamps in dome-shaped steel reflectors with glass tops give an intensity of 5 ft.-candles on the working surfaces and provide sufficient spread of light for the rest of the room. *F*—Photograph taken at night showing a section devoted to sawing and shaping in the Berkey & Gay plant, Grand Rapids, Mich. A general lighting system of R. L. M. standard dome reflectors and 200-watt Mazda C lamps hung 12 ft. high and spaced one per bay provides an even intensity of 4 ft.-candles augmented by the light-colored material.

and bowl-enameled Mazda C lamps give the best results and in the woodworking industry this equipment is found in a majority of the better-lighted plants. This reflector is very durable and relatively inexpensive and when used in conjunction with the bowl-enameled Mazda C lamps furnishes well diffused illumination at high efficiency. Such lighting units work equally well whether the system be of the general or localized variety.

Illumination at Machines Should Be Five to Seven Foot-Candles

The first process which the wood goes through when it reaches the woodworking plant is that of drying. As a rule the kilns are painted black inside and have no illumination whatever, as it is not necessary. It is a good plan, however, to provide angle-type reflectors with bowl-enameled Mazda C lamps in front of the entrance to the kilns so that the lumber may be easily loaded and unloaded. One such reflector with a 100-watt bowl-enameled Mazda C lamp hung 7 ft. high in front of each kiln will give excellent results.

As previously stated, general il-

lumination is to be preferred where it is practicable to use it, otherwise a more localized system is more suitable. In any event an intensity of illumination of from five to seven foot-candles at the machine is desirable. When localized general illumination is needed the different machines require different arrangements of lamps and reflectors. In the following paragraphs are some details which apply to lighting various machines.

Saws.—For circular saws the lighting unit should be located above the saw table, in line with and a few inches forward of the center of the saw. If the next machine is from 7 to 10 ft. away, a 150-watt bowl-enameled Mazda C lamp should be used, the reflector being hung approximately 8 ft. high. With spacings over 10 ft., 200-watt bowl-enameled Mazda C lamps should be used and hung higher in proportion. In either case R. L. M. standard dome reflectors should be provided. Bandsaws should be lighted with similar equipment, with the lighting unit hung in front of and slightly to the right of the cutting edge. Fig. 2, *E*, shows an excellent example of the practice outlined as applied to bandsaws.

Planers. — Surface planers may usually be well lighted by one lighting unit over the feed ends. If the planers are approximately 10 ft. apart the lighting units should be hung at least 8 ft. high and should consist of 150-watt bowl-enameled Mazda C lamps in R. L. M. standard dome reflectors. For greater spacings 200-watt bowl-enameled Mazda C lamps should be used and should be hung proportionately higher. This relatively wide spacing of the lighting equipment will give enough overlap of light to illuminate the delivery ends sufficiently. See Fig. 3. In case there are too many overhead obstructions to permit the proper light distribution it will be necessary to equip the delivery ends with a lighting unit. A 75-watt bowl-enameled Mazda C lamp in an R. L. M. standard dome reflector will give the desired results.

Shapers.—The lighting requirements for shapers are like those for buzz planers and consequently a similar arrangement of lighting equipment will prove satisfactory, as indicated by the night view in *F* of Fig. 2.

Borers.—In most cases it is desirable to furnish a lighting unit for

D

E

F

each boring machine. Placing the unit slightly to the right and toward the front and hanging it approximately 7 ft. high is the most desirable arrangement. (See Fig. 2, *D*.) Either 100-watt or 150-watt bowl-enameled Mazda C lamps in R. L. M. standard dome reflectors may be used.

Sanders.—There are several types of sanders and each of these requires different treatment as regards lighting. Sanders of the endless-belt type may be satisfactorily lighted by the same method as employed for surface planers, see Fig. 3. The requirements for disc sanders are practically the same as for band saws and they may be lighted in a similar manner. Sanders of the swinging-arm type may be grouped into two classes: Those with small tables and those with large tables. Sanders with small tables may be lighted by one lighting unit consisting of a 100-watt bowl-enameled Mazda C lamp in an R. L. M. standard dome reflector over each, with a hanging height of 7 ft. Large tables will require either a 150-watt or 200-watt bowl-enameled Mazda C lamp in an R. L. M. standard dome reflector, and the units should be hung approximately 10 ft. high.

Lathes.—The unit scheme of lighting, one lamp per machine, is applicable for lathes. A 150-watt bowl-enameled Mazda C lamp should be used with an R. L. M. standard dome reflector, hung approximately 9 ft. high and located at the right of the chuck and slightly towards the workman.

Bench work.—As various kinds of work are done at the benches, it is logical that different intensities will be required. Benches may be divided into two general groups: Single benches 2 ft. or 3 ft. wide along the walls, and single or double benches away from the walls. Single benches along the walls should be lighted by a row of lamps suspended about 6 in. in from the forward edge of the bench and spaced on 6-ft. to 10-ft. centers with from 40-watt to 100-watt all-frosted or bowl-enameled Mazda lamps in deep bowl or R. L. M. standard dome reflectors. If general illumination is being used for the plant with the outlets symmetrically spaced as, for example, four outlets on 10-ft. centers per 20-ft. bay, it is frequently feasible to move the first row of outlets 2 ft. or 3 ft. nearer to the wall than they would be spaced for a strictly symmetrical arrangement, and thus obtain satisfactory bench lighting with but little sacrifice of general illumination and a minimum number of outlets.

For benches away from the walls, general illumination is quite satisfactory. Only a fairly close spacing of outlets is necessary, that is, not over 10-ft. or 12-ft. centers under ordinary conditions. For work of an especially fine nature or in case of low ceilings, localized general illumination similar to that recommended for the benches along the wall would be more satisfactory. In general an average intensity of illumination of 6 ft.-candles should be provided.

Of course, in the case of cabinet work and high-grade furniture making more attention is given to exactness and details, and consequently a higher intensity of illumination is needed than in the general run of woodworking plants. A minimum intensity of 7 ft.-candles should be provided. As polished surfaces are dealt with to a large degree, it is very essential to have the light well diffused in order that annoying reflections may be minimized.

Color work. — The question of matching different woods should also be given consideration. Not only is it necessary to match them according to the grain, but also for color, especially in the case of inlay work. When color discrimination is essential the simplest arrangement to get the proper kind of light is to use Mazda C daylight lamps in the regular types of reflecting equipment. This kind of lamp is similar in construction to the Mazda C lamp, except that the bulb is made of a special blue glass and the filament burns at a higher temperature. The resultant light is whiter than that given off by the regular lamp and consequently colored objects when shown under this light appear more nearly in their true values. The daylight lamp is of lower efficiency, due to the absorption of certain rays by the blue glass, and in planning for a given intensity approximately 35 per cent more wattage should be provided to obtain the same intensity as when using clear-bulb Mazda C lamps. (*Continued on page* 557)

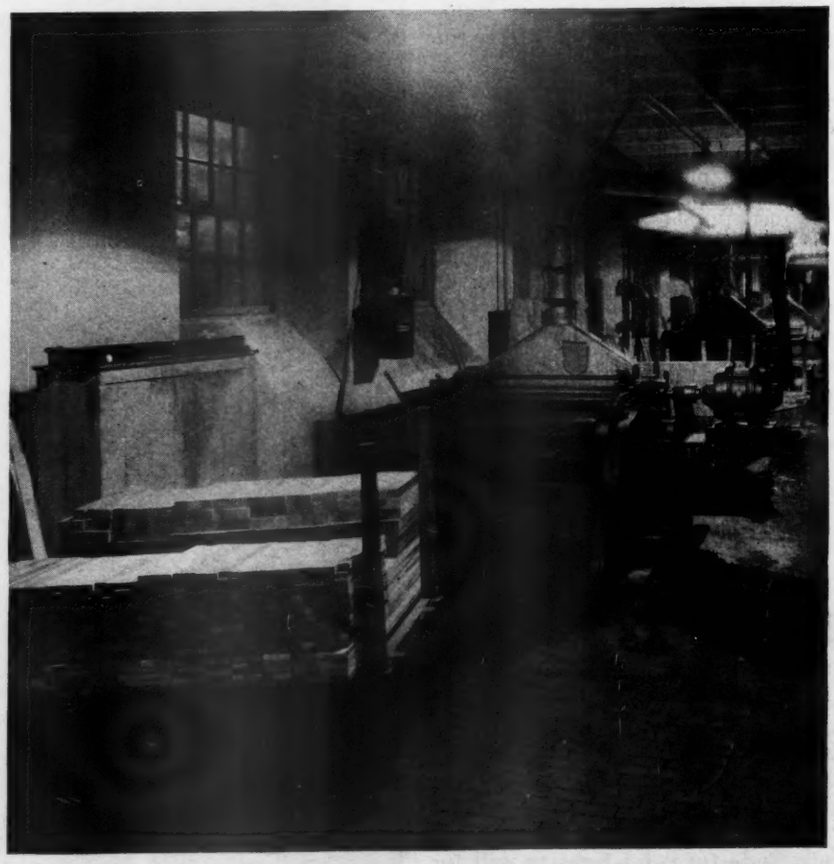


Fig. 3—Localized general lighting in a planing department.

The feed side of each machine is lighted by a 200-watt Mazda C lamp in an R. L. M. standard dome reflector, hung 10 ft. high. The illumination at the work is 6 ft.-candles and in the storage areas 3 ft.-candles. This is part of the Berkey and Gay Furniture Company, Grand Rapids, Mich.

Details of a Special Treatment for

Motors in Steamy and Wet Places

That Will Lessen Interruptions of Power Service

By NORMAN B. SMITH

Chief Electrician, Swift & Company, Chicago, Ill.

These 25-hp. motors drive sausage-meat hashers and are washed out with boiling water at the nightly clean-up. The average length of service is 9 months.

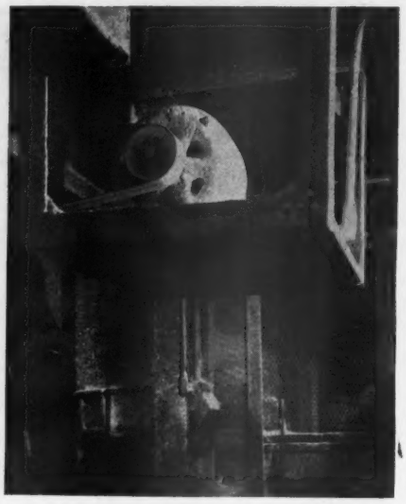
MOTORS which drive the various forms of mechanical equipment used in a modern packing plant operate, in the majority of cases, under conditions which are so very severe as to constitute a most rigid test of the varnish and other insulating materials used in their construction. The maintenance and repair problems which are thus presented are further complicated by the fact that anything more than momentary interruption of service cannot be tolerated. Excuses or explanations will not prevent the serious damage which shutdowns can cause to the large amount of highly perishable products which are always in process. Continuity of service must be maintained at any cost. At the Chicago plant of Swift & Company an effective solution of this problem has been developed and comprises a detailed inspection at frequent intervals of all motors in operation, the maintenance of an ample reserve of spare motors, equipped with the proper size pulleys, and a special treatment, when repairing, which it is conservatively estimated adds 100 per cent to the life of a rewound motor, as compared to the normal life of a new motor.

Approximately 1,300 induction motors, totaling 20,000 hp. are in use. These operate at 220 volts, 60 cycles, 3 phase, and with a few exceptions range in size from 1 to 55 hp. The majority of the motors are from 5 to 20 hp. capacity. The experience of this company with motors which are especially designed or treated by the manufacturer in an effort to make them better fitted to stand the conditions of service, has not been encouraging. Ordinarily, the extra cost of such motors is not warranted by the life of the coils, for in many instances these stand up very little or no longer than coils which have received only the treatment that is ordinarily given by the manufacturer. In consequence, standard 40-deg. motors are purchased, placed in service without any preliminary treatment and allowed to remain until serious trouble or failure necessitates their replacement.

WHEN MOTORS must operate with the minimum of interruption to service under the conditions which obtain in packing plants, the ingenuity and skill of the repairman are taxed to a high degree. In the following pages Mr. Smith explains in detail the inspection and repair methods employed in the maintenance of the motors in the Chicago plant of Swift and Company. These methods are the result of many years of experience and are so effective that a rewound motor can confidently be expected to give 100 per cent longer service than a new, standard motor.

MOTORS IN THE VARIOUS DEPARTMENTS ARE SUBJECTED TO DIFFERENT CONDITIONS

Moisture is, of course, the cause of most of the motor trouble. In some of the departments fairly low temperatures must be maintained; consequently there is excessive condensation of moisture, so that, although a motor will keep reasonably dry during the day, through the heat developed while it is in operation, as soon as it is shut off and cools down it becomes dripping wet. In other departments the temperature is high and owing to the nature of the product itself—meat—and the large amounts of steam and hot water used for heating, washing and other purposes, the air is always saturated with moisture. Strictly speaking,



The motors in the soap house look like this.

The cleaning powder made in this department for household use contains powdered soap, soda ash and fine sand. The finely pulverized material settles out of tne air as a thick incrustation which clogs the air gaps of the motors and eventually prevents the rotor from turning. In the repair shop it is necessary to remove this incrustation by means of a stream of boiling water. In time the alkali in the material decomposes the varnish and rots the insulation on the wire.

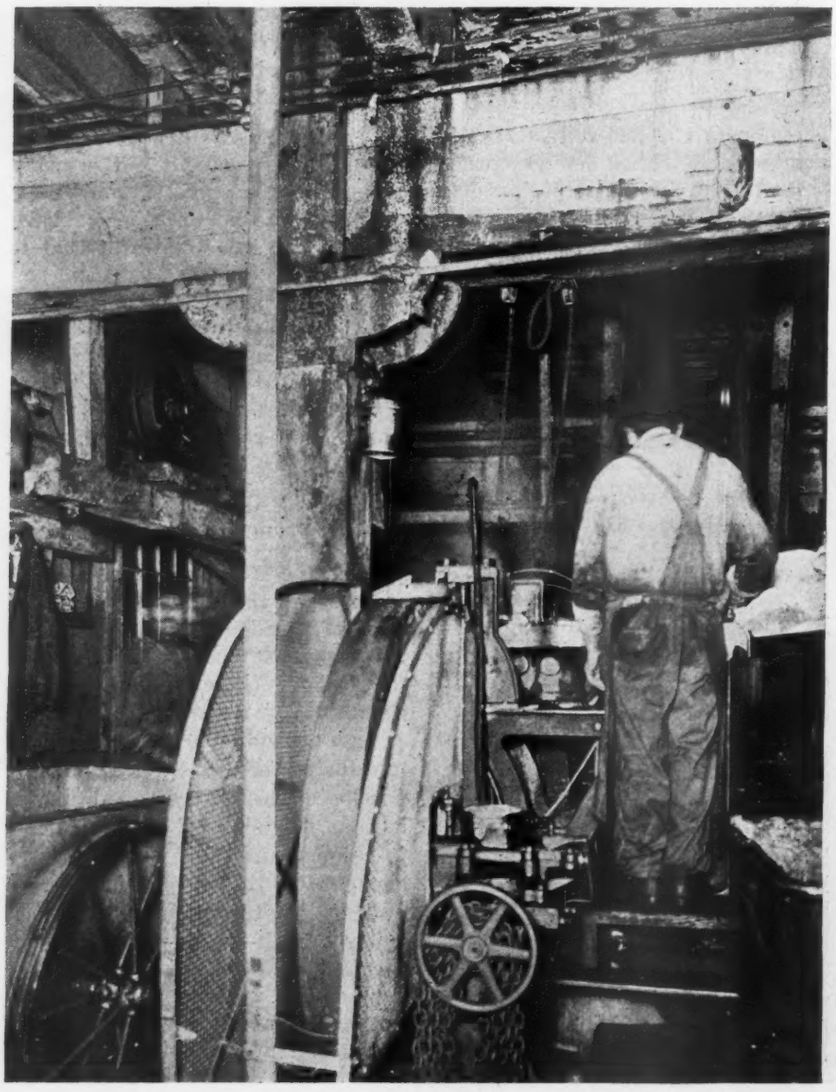
there are no corrosive gases or fumes in the air, although in the hog cutting and tankage boiling departments, for instance, some corrosive action is noticeable. This is possibly caused by the presence in the air of small quantities of volatilized animal fats or oils which condense along with the moisure and upon oxidation or decomposition produce a certain amount of organic acid that exerts some corrosive effect.

Large amounts of ordinary table salt are used in the manufacture of cured meats and other products and so the motors in these departments are exposed to the deleterious action of this substance. In the presence of much moisture or water, salt can be the cause of serious trouble, through its corrosive action.

Another and rather peculiar condition, in so far as motors are concerned, is met in the soap and particularly the cleaning powder departments. Here the product is a cleaning compound which consists of soap, soda ash, which is a rather strongly alkaline substance, and very fine sand. In the process of grinding this mixture to a fine powder and sifting or screening it, a large amount of dust is produced and settles in a thick coating over the motors, machinery and so on. Naturally, this dust works its way into all parts of the motor and tends to form a rather hard incrustation. So that, although the motor inspector blows out as much of it as possible when he makes an inspection, it is impossible to remove all of it. In consequence, the air gap between the rotor and stator frequently becomes so choked that the rotor cannot turn and the motor is put out of commission. Incidentally, when such motors are taken to the repair shop it is necessary to melt or dissolve out the powder with a stream of boiling water before the rotor can be removed.

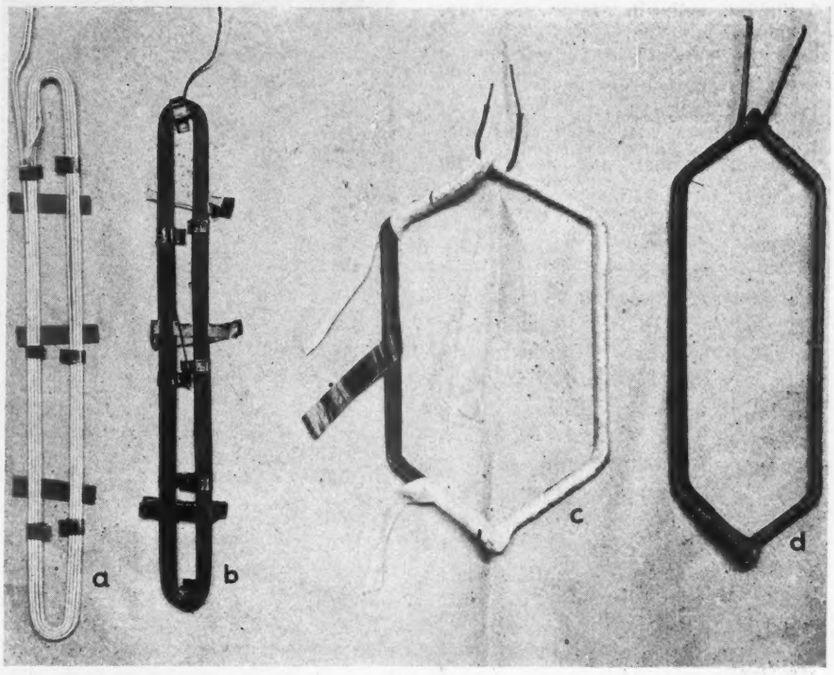
In addition, this powder exerts a very deleterious effect in that the alkali in it slowly decomposes the insulating varnish with which the coils are impregnated and also rots the tape and other insulating materials so that the wire at the ends of the stator coils is often bare when a motor is brought in for repairs.

Sanitary considerations demand that the greatest possible cleanliness be obtained throughout the plant and in the effort to secure this the machines and floors and, in many departments, even the walls and ceilings are thoroughly washed down every night with streams of boiling water. It is necessary to use hot water for this purpose, because in addition to the sterilizing effect which it exerts, it is the easiest way of removing the film of fat and grease which covers the machines



Here is a motor which operates close to a tank of boiling water in a cold room.

This motor drives a back-fat crimper. Long strips of fat from the back and sides of the hogs are passed through corrugated rolls in this machine to put them in better condition for rendering. The room temperature is about 60 deg. F. The steam from the tank of hot water for heating the rolls can be seen at the left of the operator. The condensation of moisture is excessive, but this 10-hp., rewound Lincoln motor has been in service here for about 5 years.

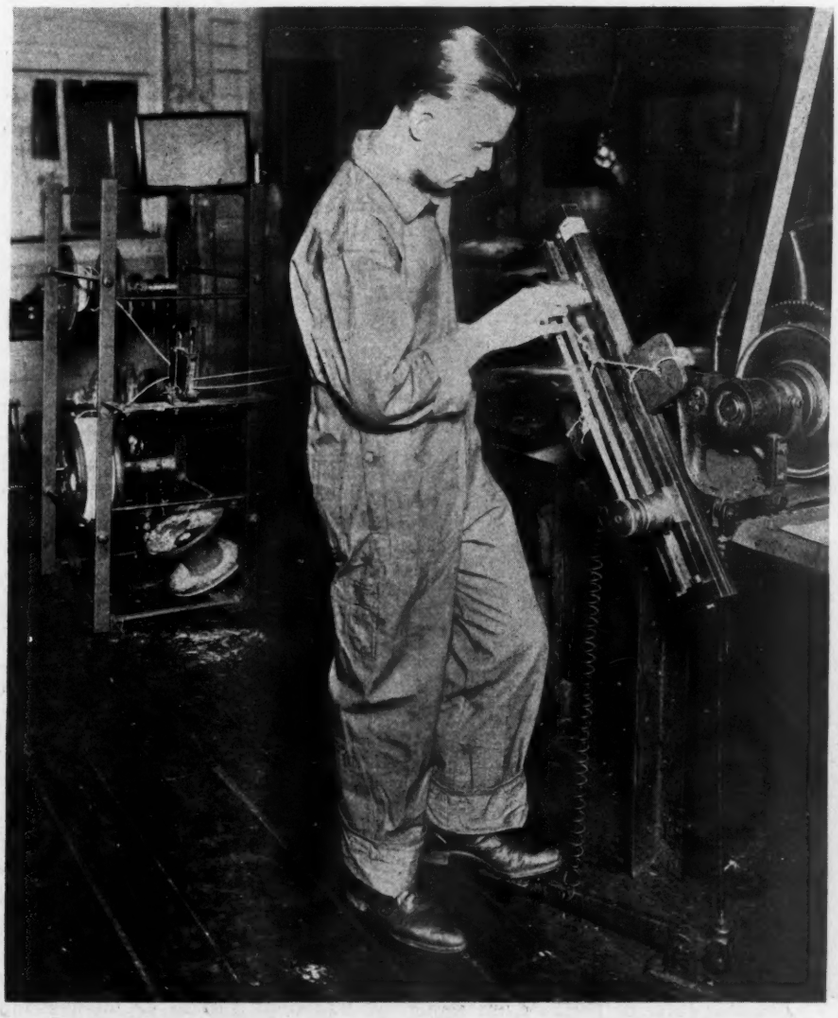


Four steps in making new stator coils.

A—Loop for 20-hp. General Electric motor as it comes from coil winding machine. *B*—This loop has been dipped in Sterling or Ajax clear baking varnish and baked for 10 hours at 212 deg. F. *C*—After forming on a Segur machine, the coil is wrapped with ¾-in. strips of varnished cambric, .007 in. thick. A layer of white cotton tape ¾ in. wide and .007 in. thick is then put on over the varnished cambric. *D*—Completed coil, ready for use. After the white cotton tape is put on the coil is dipped in insulating varnish and baked for 20 to 24 hours at 212 deg. F.

and floors. While this method of cleaning is highly effective in securing the desired ends, it is not conducive to a long life of the coils in the motors for, of course, these are treated by the cleaning gangs exactly as any other piece of equipment and are thoroughly flushed out every night. This is a very severe condition of service and one to which the motors in very few, if any, other industries are subjected.

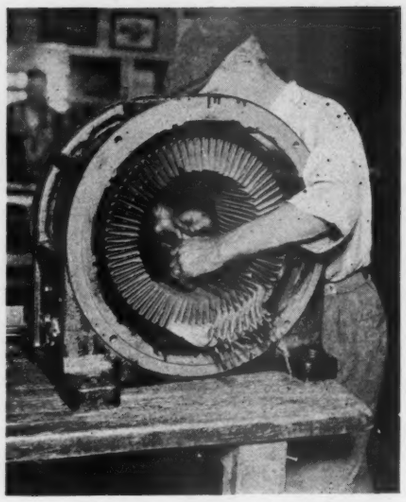
The inspection of all of the electrical equipment is handled by four inspectors who report to the Chief Electrician and are in effect charged with the responsibility of seeing that everything is kept in working order. The entire plant is divided into four sections and one man is assigned to each section. Periodic inspections are made of all motors, compensators, fuses and so on, the interval between inspections depending on the severity of the conditions under which the motor operates. Thus, some motors are inspected two or even three times a day. Others operating under more favorable conditions are inspected at intervals ranging from once every day to once every week or so. The inspection consists in testing the air gap with a feeler, touching the bearings to determine abnormal temperature, and so on.



New stator coils are made in the repair shop on a Segur machine. The operator is winding coils for a 20-hp. General Electric motor.

In this connection it may be said that most of the trouble with motors shows up at starting time in the morning, and it is not hard to see the reason for this. During the day the motor will develop enough heat to keep dry, but at night the condensation of the moisture in the air and the cleaning process, previously described, to which many of the motors are subjected wets the coils thoroughly, while the ten- or twelve-hour period between stopping and starting time provides a good opportunity for moisture to seek out the weak spots in the insulation. Eventually this is broken down sufficiently to cause a ground or short which is revealed when an attempt is made to start the motor in the morning.

The importance of maintaining



Placing coils in stator of 20-hp. motor.

After winding these coils were dipped in Sterling clear baking varnish and baked for 10 hours at 212 deg. F. They were then wrapped with .007 in. varnished cambric, ¾ in. wide, taped with .007 in. white cotton tape, ¾ in. wide and again dipped in insulating varnish and baked for 24 hours at 212 deg. F. When the coils are all in place they are connected up and the motor tested to make sure that there are no grounds, shorts or other defects.

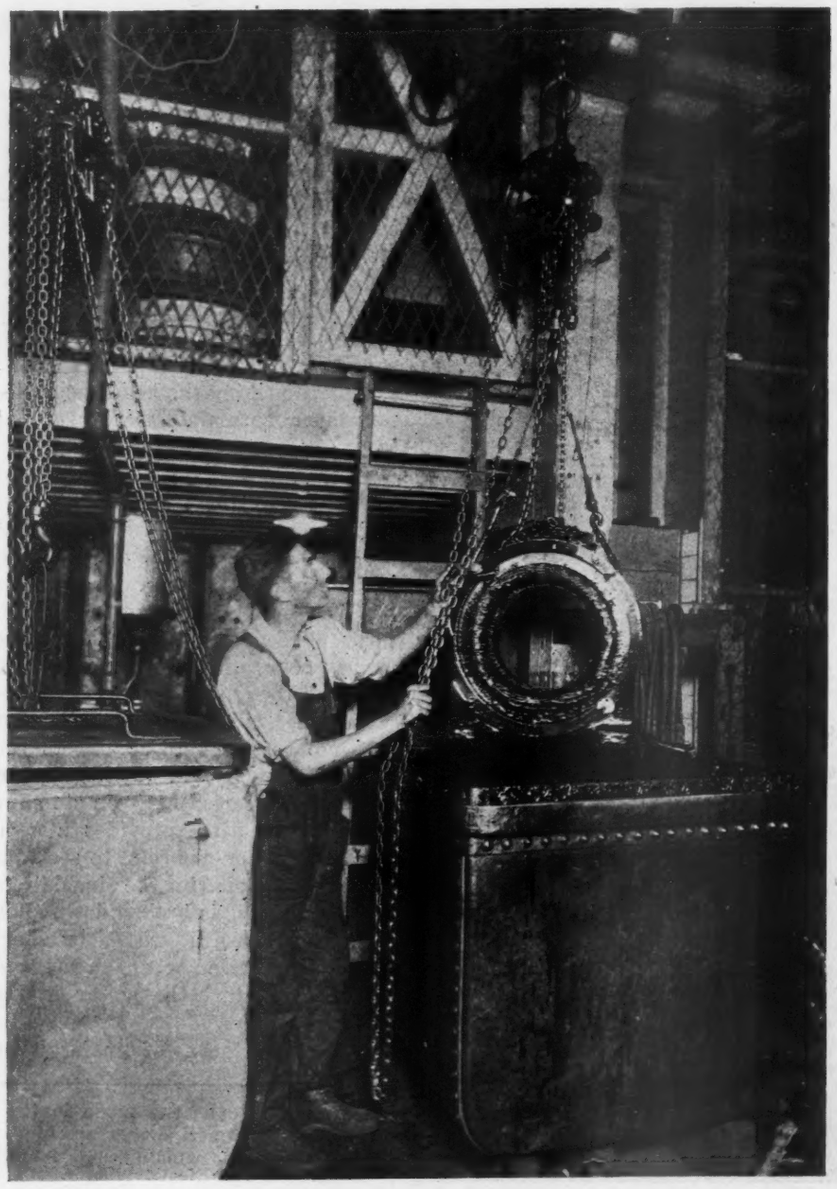
motor service was mentioned at the beginning of this article and in furtherance of this, it is the duty of anyone who detects motor trouble to report it at once, either to his superior or directly to the Chief Electrician. A troubleman is then immediately sent out to investigate. If the trouble is something which he can remedy, he does so. If the job is too big for him to handle, he reports back to the Chief Electrician, describing the nature of the trouble and the measures necessary to restore service, after which the orders necessary for putting these measures into effect are immediately given.

The same general procedure is followed in the case of trouble with the lighting system which comprises some 20,000 lamps. Despite the size of the power and lighting system and the severity of the conditions to which all of the equipment is exposed, the many problems encountered in maintaining continuity of service have been solved so successfully that three troublemen, working in shifts of eight hours each, are able to handle all the work of this nature.

Special Treatment Is Given to All Motors Rewound in the Repair Shop

When a motor is received in the repair shop for rewinding, usually the first step in the process of putting it again into working condition is to direct a stream of boiling water against it, to remove the accumulated grease and dirt. Experience has shown that it does not pay to attempt to repair or replace damaged coils. Although it is not a difficult matter to do this, the chances are that some of the other coils are in such condition that failure will take place within a comparatively short time. Consequently, all of the coils are removed and replaced with new ones. Motor repair work is handled by a corps of three experienced repairmen and three helpers.

All coils are wound in the repair shop on a Segur coil winder and double-cotton-covered enameled wire is used. After the loop is wound, thin metal clips are put on the sides to hold the wires in place and the loop is then dipped in Sterling or Ajax clear baking varnish and allowed to soak until no more air bubbles are given off. The loop is allowed to drip until all excess varnish has run off, and is then baked for 8 or 10 hours at a temperature of 212 deg. F. in an oven heated by steam. (*Continued on page* 556)



Dipping stator in clear insulating varnish.

If a test shows that there are no defects in the coils, the stator is baked for at least 8 hours at 212 deg. F. and dipped hot in Sterling or Ajax clear baking varnish. When no more bubbles are given off the excess varnish is allowed to drain off and the stator is then baked for 20 to 24 hours at 212 deg. F. Motors which are exposed to exceptionally severe conditions are given a second dip in the varnish. The varnish tank will accommodate the stator of a 55-hp. motor. A Yale and Towne chain hoist running on an overhead track is used for handling the stators in the dipping and baking operations.

MANY TIMES those responsible for maintenance choose the types of pulleys to be installed through custom, preference or prejudice. While choosing by custom leads to standardization, it is sometimes carried too far, as each type excels in a specialized field. Standardization as to types of uses instead of for a whole plant is recommended. This article points out some of the applications of pulleys and the points to consider in choosing the type to be used for any given duty.

Some Practical Pointers on

Sizes and Types of Pulleys

For Transmitting Power Through the Lineshafting to the Machines

By FRANK E. GOODING
Associate Editor, Industrial Engineer

THE FIRST pulleys were grooved to fit round belts or ropes. Many grooved pulleys are still used, generally on small, fractional horsepower drives or on large rope drives, often transmitting many hundred horsepower. With the evolution of the modern belt the pulleys increased correspondingly in size and strength.

The first commercial pulleys were of cast iron. Generally they were a part of the machine and naturally the manufacturer would cast the pulley along with the other parts. This practice is still commonly followed on machinery as it gives a pulley which runs absolutely true and enables the machine to be constructed with less trouble. Often the purchaser obtained the shaft or countershaft pulleys also from the manufacturer of the machine. The improvement of cutting tools and of manufacturing methods necessitated changes in pulley sizes to obtain higher speed. This brought into play a new business—that of supplying pulleys of almost any size. As this business increased it changed from local made-to-order work almost exclusively to stocking certain sizes which were most frequently in demand and supplying odd sizes to order. Standard and special sizes of pulleys which may be obtained can be secured from the catalogs of jobbers or manufacturers. These sizes are not standard with all manufacturers and so will not be listed here. Men responsible for maintenance should have catalogs.

At first all pulleys were made with a solid hub and bored out to order. This made it impossible ever to use the pulley on a smaller shaft; for use on a larger shaft reboring was required. Also a cast-iron pulley is heavy to ship and store and sometimes is damaged in transportation. To overcome these objections, solid and split cast-iron pulleys with a steel rim, split and clamp-hub cast iron, split wood, and later the steel pulleys, with interchangeable bushings, were developed. Later industrial demands, particularly for driving pulleys, brought out paper, fiber and special composition pulleys. The various types of each of these classes will be discussed in order.

Three important factors in choosing any pulley are, (a), the horsepower to be transmitted, (b), the speed to be obtained and, (c), the service. The requirements of pulley construction necessitate that they be able to withstand much greater strains than ever received in service. The critical element, therefore, is the belt, which must be made the basis of all horsepower calculation. While some pulley catalogs give tables of the horsepower which a pulley can transmit, these tables are not always convenient. The stand-

Directions for Ordering Pulleys

A careful observance of the following rules for ordering pulleys will avoid errors and save time. In making out orders, describe pulleys, using sketches when necessary, and give specifications and dimensions in the following order:

1. Type of Service

State whether for single or double belt.

If neither is specified, single-belt pulleys will be furnished if listed.

If greater horsepower is required than is transmissible by a double leather belt, specify the amount of horsepower, r.p.m. and character of service.

2. Description or Type

State whether solid, split, clamp hub, tight and loose, flange, web or disc center, or special; otherwise, plain, solid pulleys are furnished.

For special pulleys send sketch showing special features. All special features bear an extra charge.

3. Diameter of Pulley

The first dimension given should be dia. in inches.

When exact dia. is required state whether measurement shall be made at crown or edge of rim.

An extra charge is made for exact diameter.

4. Width of Face

The second dimension given should be the width of belt to be used, unless an exact width of face is desired (extra charge), in which case the fact should be noted on order by having the word "exact" follow dimension of face.

5. Bore of Hub

Specify exact diameter of shaft in inches, the third dimension given.

If shaft is of an odd or special diameter, send a gage with order.

Under no circumstances send in an order for pulley to be bored "1 15/16 in. scant," "2 7/16 in. full," or "about 1/64 in. under 3 in."

Bores to gage furnished or involving fractions less than 1/16 in. (as 1/32 or 1/64) entail an extra charge.

6. Crown or Straight Face

After specifying dimensions, state whether crown or straight face.

If neither is specified, crown face pulleys will be furnished.

Pulleys for belts which do not shift should have crown face. Pulleys for shifting belts should have straight face. Each pulley of a pair of tight and loose pulleys should have crown face.

7. Keyseat or Set Screw

State whether keyseated or set screwed or both.

If neither is specified, set screws only will be furnished.

If keyseated, state whether straight or taper.

Pulleys keyseated and not set screwed should have taper keyseat.

Taper keyseats will be cut with ⅛-in. taper per foot, unless otherwise specified.

If size of keyseat is not specified, manufacturer's standard will be used. Split-hub pulleys generally have straight keyseat with set screws on top.

An extra charge will be made for pulleys both keyseated and set screwed, or having more than two set screws.

ard formula for computing the horsepower is:

$$\frac{\text{Speed} \times \text{width} \times \text{tension}}{33{,}000} = \text{horsepower}$$

In this use the speed in feet per minute, the width of the belt in inches and the belt tension per inch in width as 40 lb. for single, 65 lb. for double and 90 lb. for triple ply belt. Allowance must be made if the belt has less than 180 deg. arc of contact on the pulley. Although the horsepower transmitted varies with all of these factors industrial conditions usually fix at least two of them—the tension and the speed—which leaves only the width to be determined. The chart, Fig. 6, gives the rim or belt speed in feet per minute when the r.p.m. and the diameter of the pulley are known. It may also be found by the following:

Rim speed, in ft. per min.=0.2618 ×dia. (inches)×r.p.m.

Of course a loose belt will not have this tension and transmits less horsepower. A greater tension stretches the belt until finally, if stretched too much, the life or elasticity of the belt is destroyed. The flexibility of belts under intermittent loads is dependent upon the give and take of live leather. High tension is also hard on the bearings of machines or shaft hangers. It is far better when possible to run a belt an inch wider at less tension and so lengthen the life of both bearing and belt. While this increases the initial cost of pulley and belt it means uninterrupted service which in many instances is worth several times the additional expense.

Frequently it is possible to increase the belt speed by adding larger pulleys, as between jackshafts, and so get a higher transmission of power with the same belt. If the pulley ratios are maintained, the r.p.m. is not changed. This is often done when a pulley will hardly pull a load and it is not desired to buy a wider belt.

The speed of the lineshaft and that of the machine to be operated are usually fixed; so that the intervening pulley must be of a certain size which will maintain this ratio. Probably one of the most important causes of trouble in the shop lies in trying to use a narrow pulley and belt just because they happen to be on hand. Continuous attention to bearings and belt, with the consequent interruption of production, are not economies. A new pulley can be obtained within a few days at the most unless it is a special size. Planning ahead, and with well organized maintenance work changes are usually known in advance, will give time to get a new pulley.

Types and Uses of Cast-Iron Pulleys

Cast-iron pulleys are made in a wide variety of types for practically any purpose. Most of the various types are shown in the pulley chart, Fig. 1. The trade terms which are used in ordering are given underneath the individual illustrations. When ordering pulleys it is well to send in a rough sketch particularly if the hub is not of the standard as shown in No. 1 of this group. Nos. 8, 9, 10, 11, 12, 13 and 14 show common variations which must be specified and dimensioned when ordering. All of these are considered as specials and are made to order at an extra charge.

Ordinarily in ordering pulleys the diameter is given first, the width next and finally the bore. Width is usually specified as the width of the belt to be used. Generally the pulley is ¼ in. or more wider than the belt unless an exact width is specified. For example, if a 10 by 6 by 1¾ in. cast-iron pulley were ordered without other specifications the customer would get a *solid* pulley 10 in. in dia., face about 6¼ in. actual measurement, bored to 1¾ in. exact and made for a single belt. In addition most manufacturers would assume that it was wanted crowned, the hubs would be unfaced, and set screws only provided.

All necessary information on ordering a cast-iron pulley is given in the box on this page. This information has been compiled by T. B. Wood's Sons Co., Chambersburg, Pa.

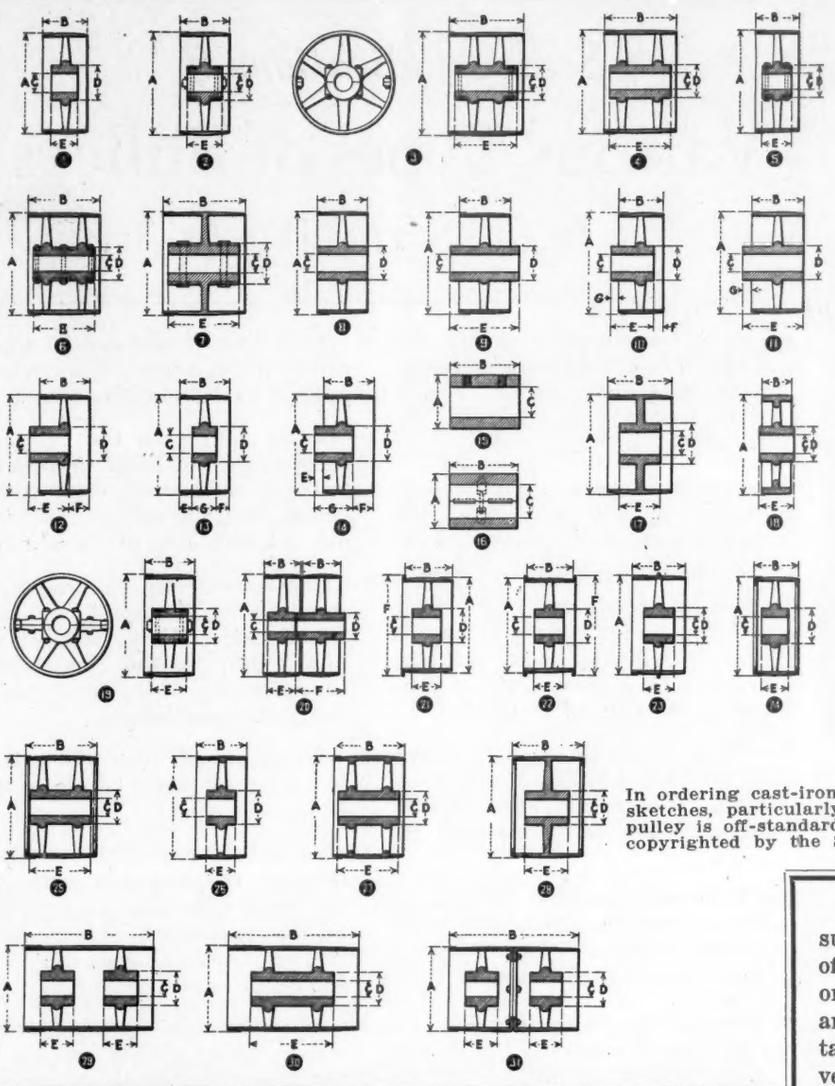


Fig. 1—Specifications and names of various types of cast-iron pulleys to be used when ordering.

The names commonly applied to these types are as follows:

1—Single arm, standard hub, solid.
2—Single arm, standard hub, split.
3—Double arm, standard hub, split.
4—Double arm, standard hub, solid.
5—Single arm, clamp hub.
6—Double arm, clamp hub.
7—Solid web, clamp hub.
8—Hub flush with face on both sides.
9—Hub extended, both sides.
10—Hub extended, one side.
11—One hub extended, other flush.
12—One hub extended, other flush with arms.
13—Extra short hub.
14—Arms offset, one hub extended.
15—Solid sleeve pulley, 3- to 6-in. dia.
16—Split sleeve pulley, 3- to 6-in. dia.
17—Solid web pulley.
18—Balance wheel.
19—Split hub, arms and rim.
20—Tight and loose, standard hub.
21—Single flange, solid hub.
22—Double flange, standard hub.
23—Center flange, standard hub.
24—Single arm, flanges under rim.
25—Double arm, flanges under rim.
26—Single arm, center rib.
27—Double arm, double rib.
28—Generator or motor pulley, solid web, flanges under rim.
29—Conveyor head pulley, double arms and hubs.
30—Conveyor head pulley, double arms, single hub.
31—Conveyor head pulley, double arms and hubs, bolted flanges.

In ordering cast-iron pulleys it is well to always send sketches, particularly if the hub or any other part of pulley is off-standard. This chart is adapted from one copyrighted by the Stephens-Adamson Co., Aurora, Ill.

Instructions of most other manufacturers closely approximate these but it is seldom safe to give only the dimensions without adding "dia.," "width" and "bore." Even then it is always best to be safe and send a sketch with all dimensions plainly indicated. Many of these specifications also apply to other types of pulleys.

Where the cast-iron pulley is to be used at speeds over 300 r.p.m., or for pulleys 38 inches or over used at a rim speed of over 3,000 ft. per min., it is best to obtain the advice of the manufacturer. Cast-iron pulleys can and often are used above these speeds, but it is safest to have them of special strength.

Pulleys are made for both single or double belt within certain definite sizes. The single-belt pulleys are lighter and not expected to be used on heavy work. Some of the methods of making pulleys stronger are to use double arms, solid webs, center ribs, or flanges under the rim. Split cast-iron pulleys are strengthened by making them with split arms as shown in No. 19, above.

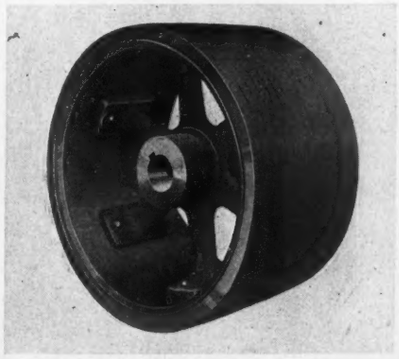
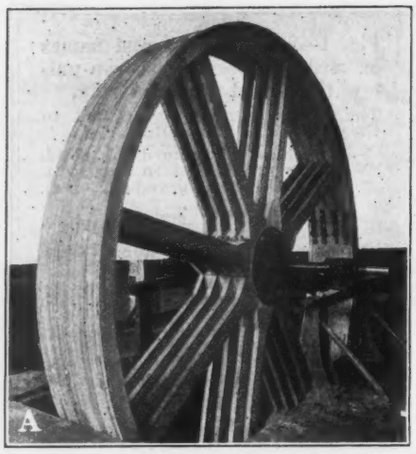


Fig. 2.—Heavy-duty, wood rim on cast-iron center dynamo pulley.

This pulley combines the strength of rim of the wood pulley with that of the arms of the cast-iron pulley. All casting strains are eliminated in this construction. These are made split, double-arm, clamp hub or solid.

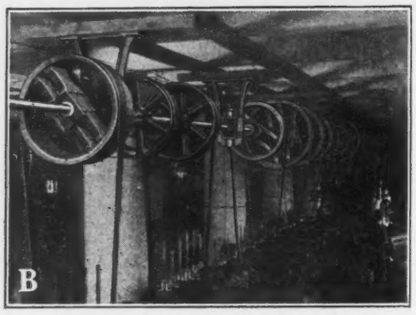
Although the crown is usually sufficient to prevent a belt running off the pulley, the addition of single or double flanges, Nos. 21 and 22, is an extra precaution which should be taken where necessary. These are very commonly used on small pulleys and narrow belts traveling at high speed and subject to a sudden heavy load which might slip and throw the belt. The center flange, No. 23, is frequently used to separate two belts driven from the same pulley. Small diameter pulleys are made either split or solid as shown in Nos. 15 and 16. Various types of special motor pulleys will be discussed in this and a following article.

Idler or tightener pulleys are made strong, to withstand heavy pressure. Generally they are of cast iron, but pulleys with a wood rim on an iron spider are used. They are seldom crowned. Because of the heavy pull most conveyor and mule-stand pulleys are of cast iron, too. When the belt does not adhere tight enough to the pulley to pull the load, the conveyor belt is frequently covered or "lagged" with rubber. This is generally necessary on the upper pulley of a vertical belt conveyor. On extra heavy pulls the belt winds



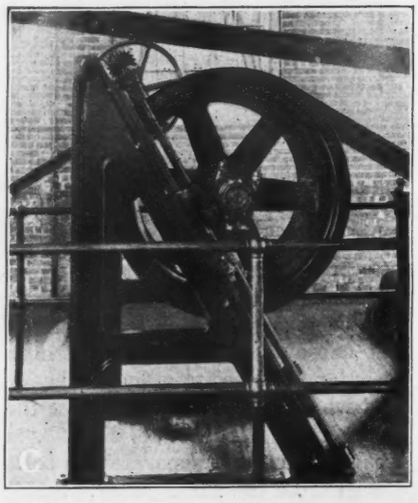
Some Applications of
Various Types of Pulleys
in Industrial Works

A—Large wooden pulleys, this one is 186 in. by 26 in., can be made to order on short notice. Fig. 8 shows how the arms are held in the rim.



B—A wide variety of pulleys is used here. The first three, for example, are: Split wood, clamp-hub cast-iron and split steel.

C—Here a wood-rim pulley with cast-iron center is used as an adjustable belt tightener. It also helps make a greater arc of contact of the belt on the pulley.



D—Paper motor pulleys drive through wood pulleys on the lineshaft. Notice that open pulleys on machines are protected by discs.

E—Wide straight-faced, split steel pulleys on the lineshaft drive cast-iron tight and loose countershaft pulleys for machines.

F—In this case heavy-duty, double-arm, wood rim with cast-iron-center pulleys are used. This intermediate jackshaft obviates the use of an excessively long belt.

G—Both wood and cast-iron pulleys are used in this paper mill installation.

H—Split steel lineshaft pulleys drive to cast-iron countershaft pulleys in this machine shop.

I—Center flanges on the first and third split wood-rim iron-center pulleys enable two belts to be driven from the same pulley without interference, in this mill.

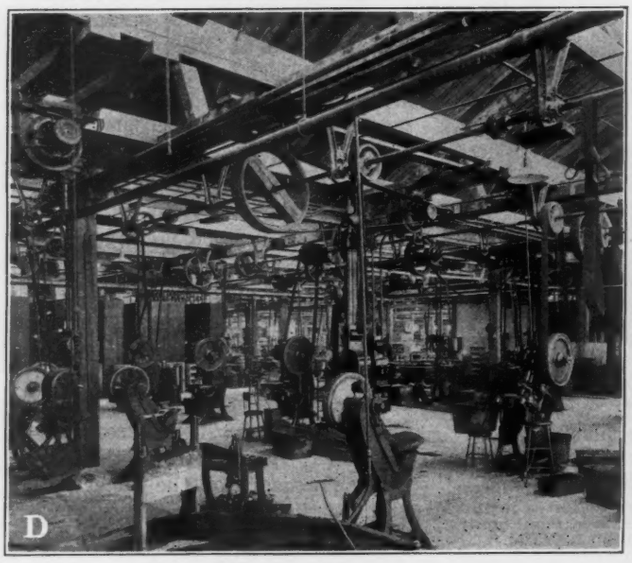
J—This installation seems to have standardized on wood rim cast-iron-center pulleys. Notice the idler pulley at the right which supports the belt as it passes above the steel beam.

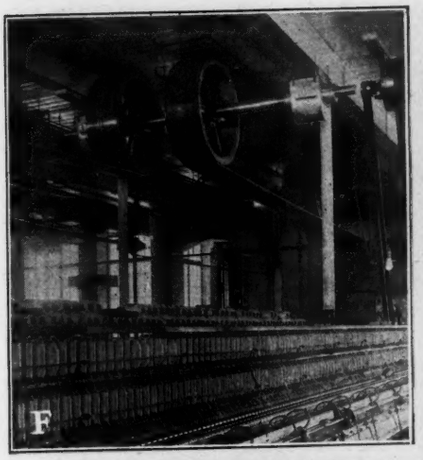
K—Wood pulleys have the preference for lineshaft work in this machine shop.

L—Variable speed is obtained through the cast-iron cone pulleys with tight and loose pulleys on the same shaft. A rope drive around the cast-iron sheave drives the countershaft.

M—This cast-iron engine flywheel was wood-lagged and grooves cut for a rope drive, which operates in two directions.

N—Some of the split wood lineshaft pulleys are "stepped" to give greater tension when on the tight pulley.

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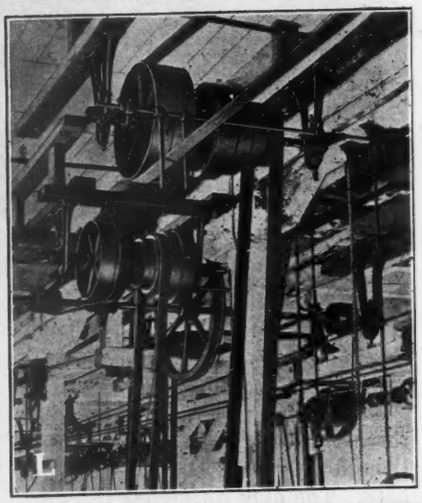
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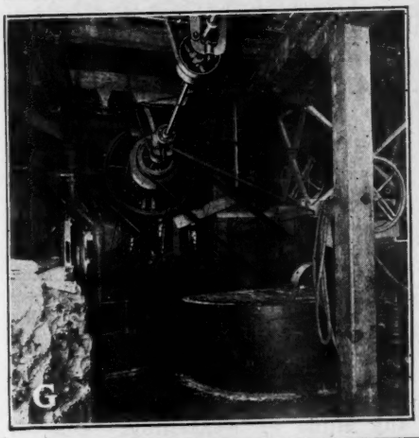
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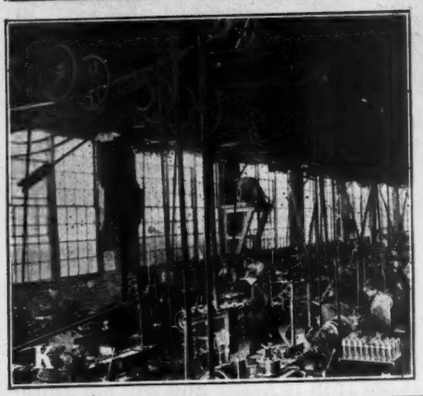
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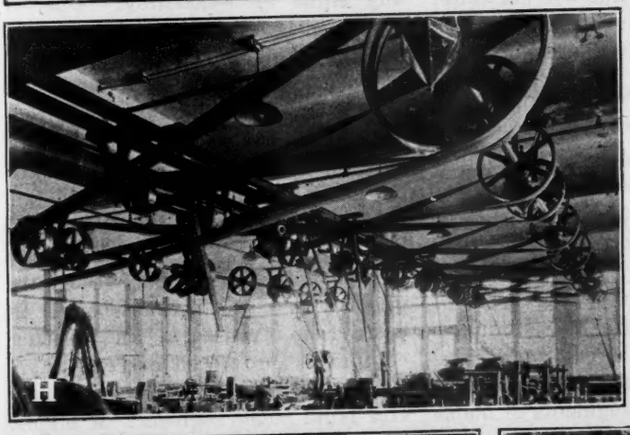
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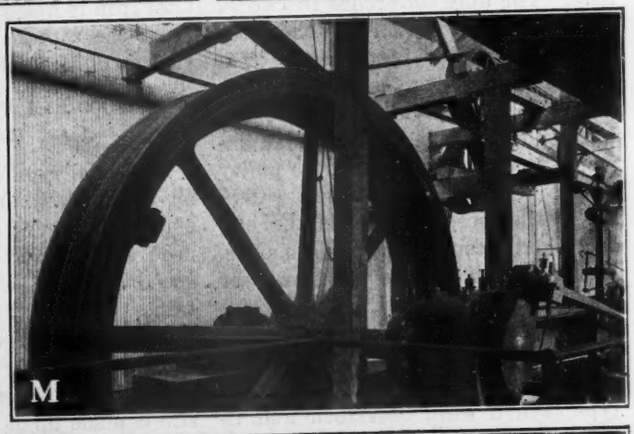
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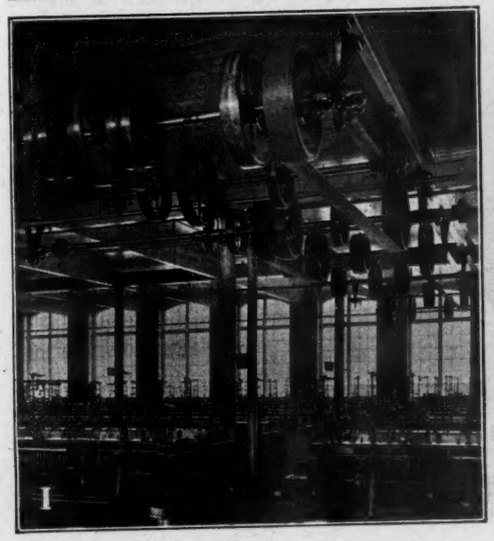
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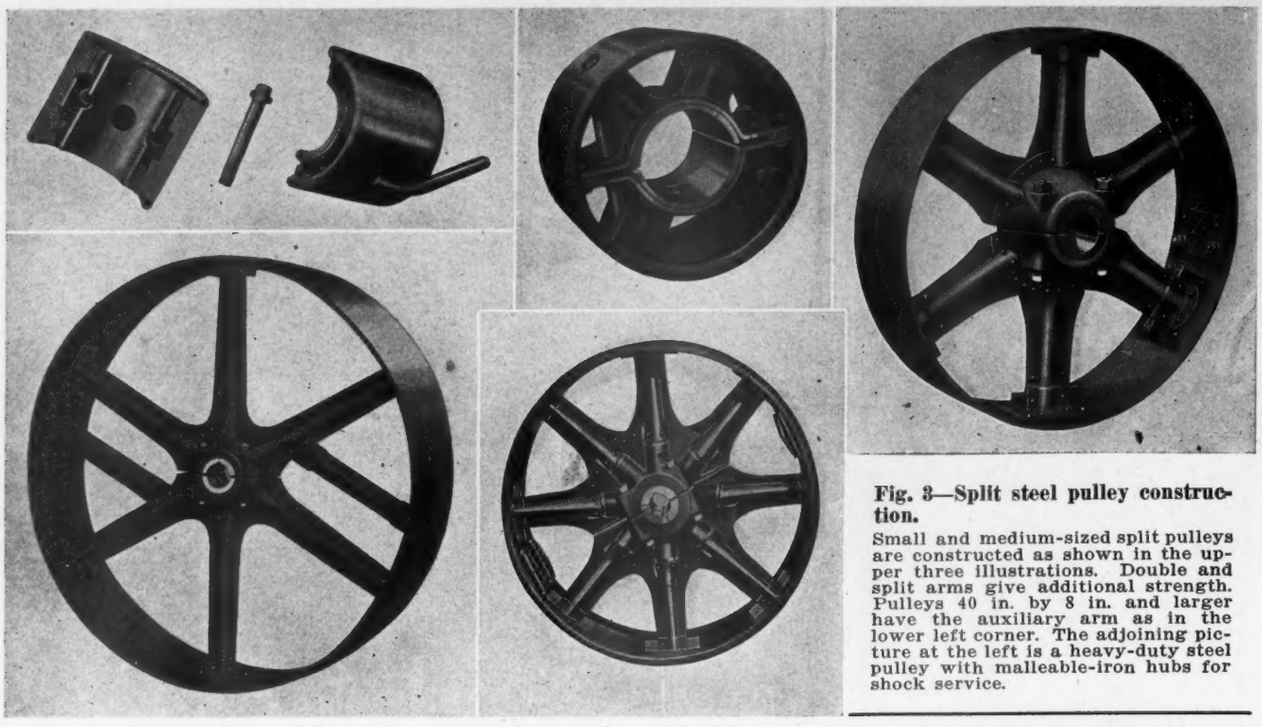


Fig. 3—Split steel pulley construction.

Small and medium-sized split pulleys are constructed as shown in the upper three illustrations. Double and split arms give additional strength. Pulleys 40 in. by 8 in. and larger have the auxiliary arm as in the lower left corner. The adjoining picture at the left is a heavy-duty steel pulley with malleable-iron hubs for shock service.

through three driving pulleys set fairly close together.

In ordering tight and loose pulleys three general types are common although only one, No. 20, is shown here. The only difference in two of these types is that in one the loose pulley is smaller in diameter than the tight pulley, to ease the belt tension when idle, while in the other both pulleys have the same diameter. In either case the loose pulley is frequently brass bushed. Generally the loose pulley has the hub faced and extended out on both sides. The tight pulley has the narrower standard hub, unfaced. Both pulleys are crowned. The pulley driving them usually has a double crown.

Ball-bearing loose pulleys, the third type, which were described and illustrated at the top of pages 428 and 429 of the September issue of INDUSTRIAL ENGINEER, are in many cases supplanting the older types of tight and loose pulleys. This is due to the better lubrication which practically eliminates the danger of hot bearings — a common source of trouble with ordinary loose pulleys.

Cast-iron pulleys, because of their weight, act somewhat as a flywheel and absorb many shocks due to intermittent loads. Particularly is this true of systems of lineshafting where a group of machines are driven from one motor. Cast-iron pulleys can be perfectly balanced and, as they are machined, can be made to run absolutely true. They are used in practically all kinds of work. However, they are recommended almost exclusively for some chemical industries especially where acid or corrosive fumes are given off. Cast iron is heavy and will not suffer from the attacks of acid vapors or rust as quickly as will steel or wood.

WOOD-RIM PULLEYS WITH CAST-IRON ARMS

A special type of wood-rim pulley on a cast-iron spider or arms, as shown in Fig. 2, is very frequently used where great strength and high speed are needed. This method retains the strength of the arms of the cast-iron pulleys but eliminates the weakness due to casting strains where the arms enter the rim. The rim is made up of segments of maple

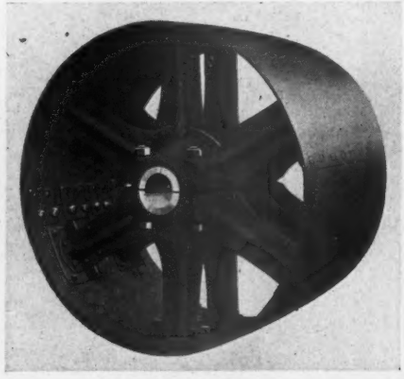


Fig. 4.—Construction to give strength to wide pulleys.

Double arms are one method of giving additional strength and stiffness to wide pulleys of all types.

wood glued and pinned together and then fastened to the spider. Under test these pulleys have been operated up to 17,000 ft. per min., rim speed, without breaking or showing any signs of weakening. Due to their construction they can be very carefully balanced and may be used on practically any kind of work where hard service is required. These pulleys are made in solid, split, and split-arm types. They are not made in the lighter types, but are designed only for double belt and heavy duty.

Frequently cast-iron flywheels are given a new wood rim when it is desired to transform an existing equipment into a belt or rope drive. This is done by building up a wood rim from small segments of maple, boring out the inside, fitting on the flywheel and then turning it down on the outside for belt or ropes.

TYPES OF STEEL PULLEYS

One of the early types of pulley, which is still used in large numbers, is steel rim on cast-iron arms and hub. This combines the lightness of the steel with the strength of the cast-iron center. This is made in solid, split or clamp hub types.

The chief advantages of steel pulleys are their interchangeability, lightness and low cost which makes it possible to keep them in stock and to obtain them on short notice. Extra strength is given by constructing with split arms, double arms and

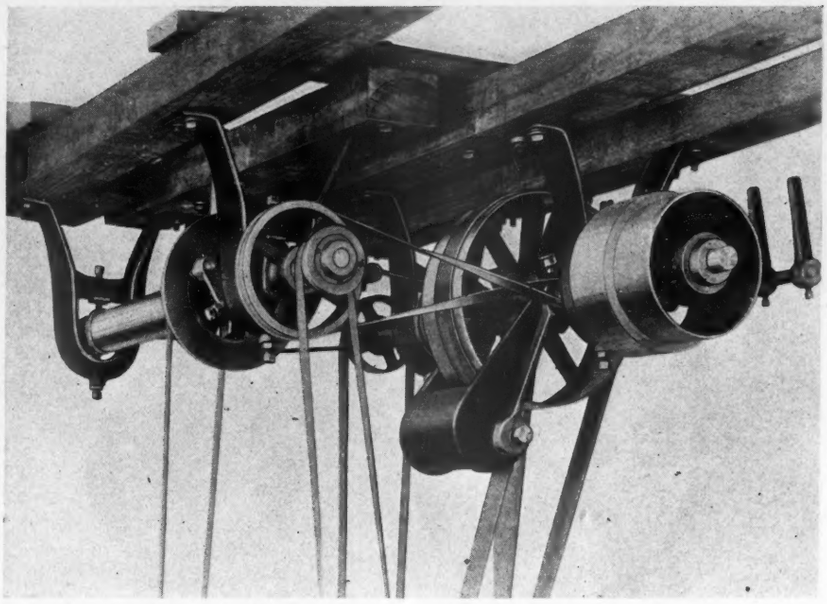


Fig. 5.—All the pulleys on this grinder countershaft are of cast iron.

Machine countershafts and pulleys are usually supplied by the manufacturer of the machine. In this case the tightener pulley is placed near the large overhead pulley to bring the two belts closer together, as it would be in the way if placed down on the machine near the small, driven pulley. A special wide-face straight pulley for a sliding belt is shown at the far end of the countershaft.

auxiliary arms as shown in Figs. 3 and 4. Heavy-duty steel pulleys may be provided which will take almost any service. By maintaining a supply of interchangeable metal bushings the steel pulley can be used on shafts of different diameters.

Steel pulleys are made with either crown or straight face. For these, as for other types of pulleys, crown faces are best for non-shifting belts or for tight and loose pulleys. Special split oil bushings are provided for the loose pulley. When a belt running first on one side of the center and then on the other is to be shifted on the face of a pulley, a straight face pulley is usually better. Pulleys to carry two belts are double crowned.

Another element in favor of the steel pulley is its safety. In case it gives way it not only gives warning through emitting peculiar sounds but crushes instead of flying to pieces. It is also not easily damaged in transportation, or, if damaged, the injury is obvious. It is seldom recommended for a motor pulley—for that matter, no split pulley is—and due to the ease with which steel is attacked by acids, and sometimes corrosion, it cannot be used in some chemical industries.

Steel pulleys, if properly installed, will run true enough for any ordinary speed. High speed and heavy duty are taken care of by specially built steel pulleys which are constructed much stronger and more carefully balanced. Steel pulleys with double flanges can be furnished in sizes from 8-in. dia. up by at least one manufacturer.

Characteristics of Split Wood Pulleys

Sometimes weight is an objection and so split wood, steel rim and steel pulleys were developed. Some of the types of split wood pulleys are shown in Figs. 7 and 8. It was through the development of the split pulley that jobbers were able to carry stocks of pulleys, as with solid cast-iron pulleys it was difficult to make provision for the wide variety of bores in addition to the numerous diameters and faces which might be called for. The varying diameter of bore is taken care of by wood bushings for wood pulleys. Split steel as well as cast-iron split and clamp-hub pulleys use metal bushings. Wood bushings may be used on steel pulleys in an emergency but are not recommended for permanent use. For heavy service keyways are cut in the metal bushings.

A big advantage of this method of bushing pulleys lies in the fact that the same pulley can be used on a number of sizes of shafting merely by changing the size of the bushing. Bushings to fit all diameters of shafting used can be kept in stock and so any pulley can be used almost anywhere in the shop.

Wood pulleys are built up from small blocks of wood glued together so as to break the grain. However, there is a sufficient amount of end grain to give a high coefficient of friction between the belt and the pulley. The particular advantage of wood pulleys lies in that they are light and cheaper than other types of pulleys. This is not only true of the standard sizes but also it is much easier to get a special wood pulley built up than a cast-iron or a steel pulley.

Wood pulleys will withstand most shop service conditions, although they are not recommended for high

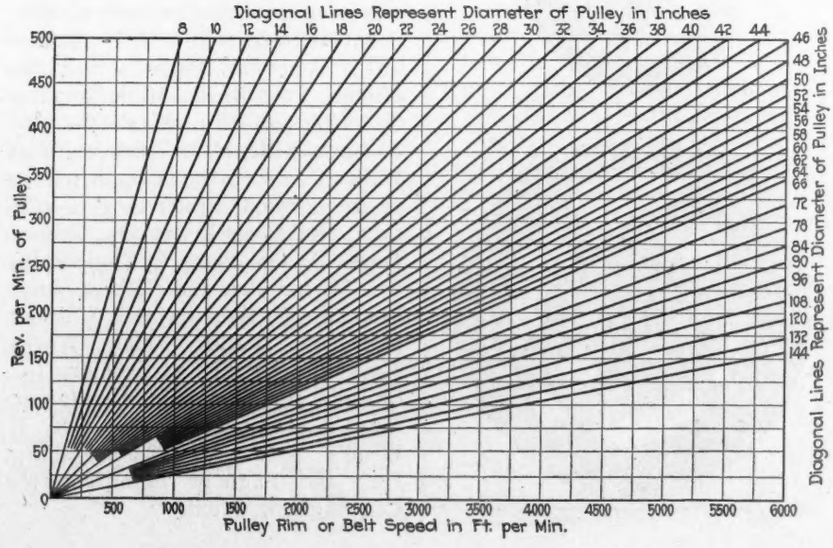


Fig. 6.—Chart for determining pulley-rim or belt speed when r.p.m. and diameter are known.

In addition, when the belt speed and the diameter of the driven pulley are known, the r.p.m. of driven shafts can be fairly closely approximated by reading the r.p.m. on the horizontal line at the intersection of the diagonal line representing pulley diameter and the vertical line representing the speed in ft. per min.

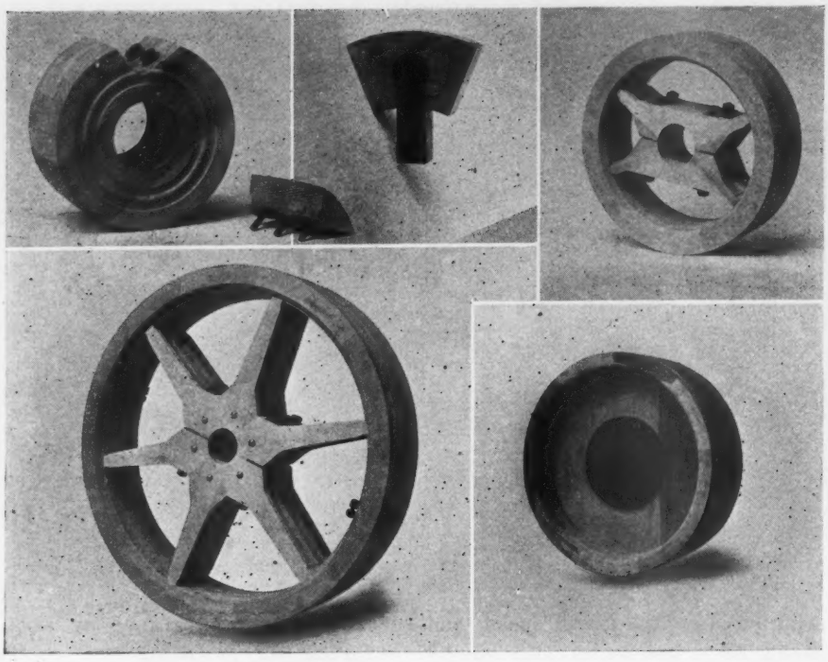


Fig. 8.—One type of split wood pulley construction.

Small split pulleys are made like the one shown in the upper left corner. A small section is removed to get at the heavy screws clamping the two halves together. The T-shaped insert indicates how the arms are keyed into the rim. The next two illustrations show the construction to maintain strength as the size increases. A solid heavy-duty dynamo pulley with iron hub and keyway is shown in the lower right corner.

speeds nor where the atmosphere is very damp. They are very popular in some localities and may be obtained not only in the standard crowned and straight rims but as specials with flanged rims, tight and loose, step-coned, and tapered pulleys. Wood pulleys may be made in large sizes easily and quickly. One large pulley is shown in illustration *A* on page 522. These are turned on the inside and outside of the rim and are carefully balanced. The method of fastening the arms in the pulley rim is shown in the illustration at the top of the page.

Every maintenance man knows that while placing a pulley on a shafting is generally not hard work, still it is usually difficult because of the inconvenience of getting at the job and holding the pulley while putting it on. The common method is to put two ladders in the best position possible and have one man on each ladder as close to the work as he can get. In this case, however, he must hold the weight out in front of him and the pulleys get rather heavy before finally fastened. The illustration at the head of this article shows a special step ladder which is used in a number of shops for work of this sort. Here, as can be easily seen, the two men are directly under the pulley and so can support it much more easily while they hold it in position until one or two bolts are finally caught. This ladder is made by the Dayton Safety Ladder Company, Dayton, Ohio.

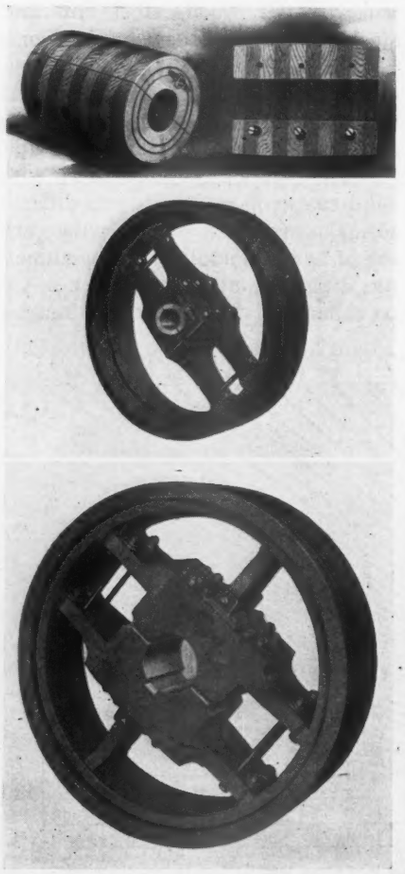


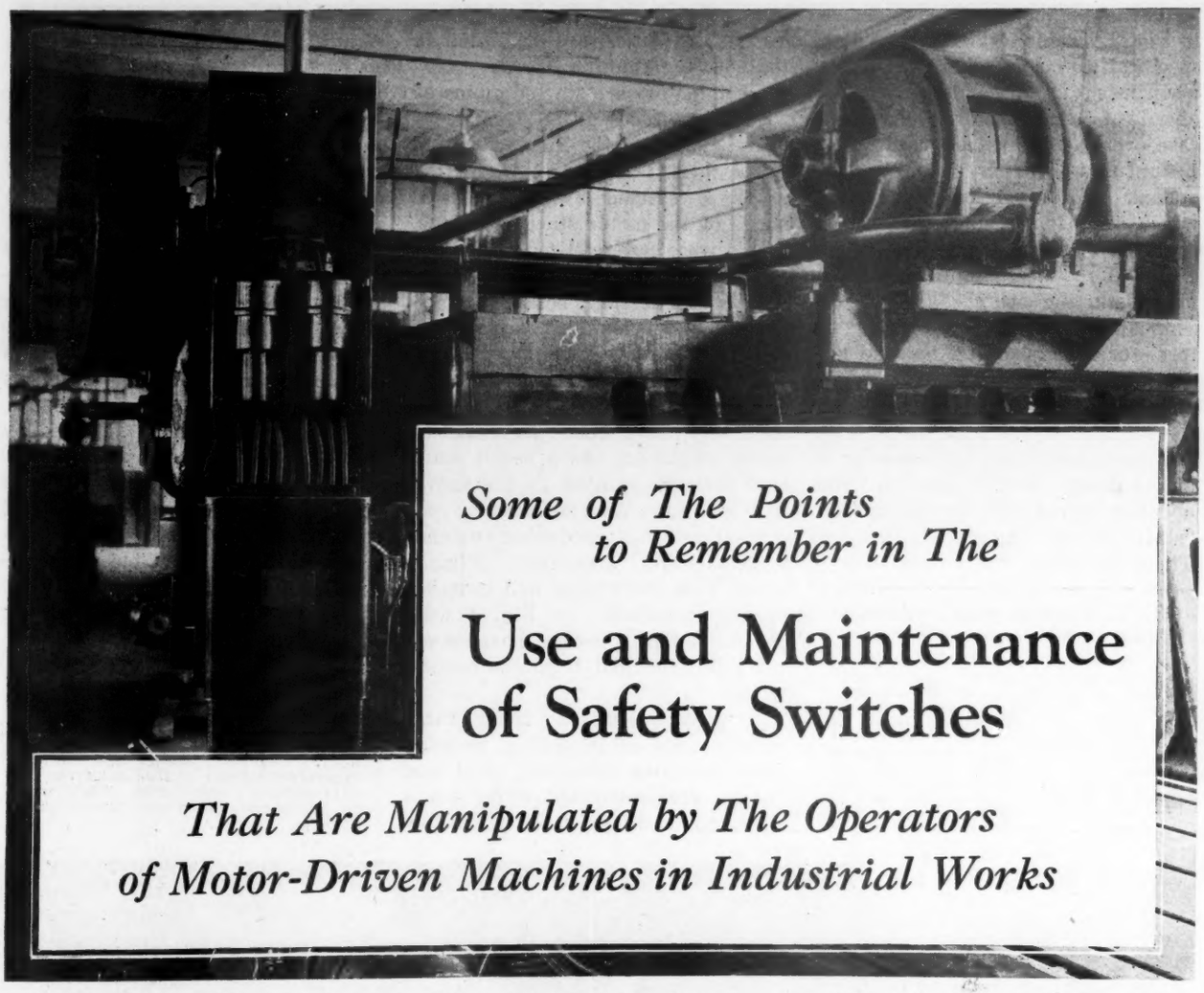
Fig. 7.—Another type of split wood pulley construction.

Pulleys up to 8 in. in diameter are built as shown in the upper of these three illustrations. Those from 9 to 30 in. in diameter, and up to 40 in., if narrow face, are of the second type. The lower pulley is of the "crushing roll" type and is built to resist shocks, as wood does not crystallize under repeated shock loads as on the crushing rolls of a concentrating plant.

Although pulleys play such an important part in the transmission of power, still they are not given enough consideration unless something goes wrong or a change is made. Many times when one type of pulley will not pull the load, the installation of another type will handle it very satisfactorily. Thus, with the cost of a pulley, the replacement of more expensive equipment is not necessary. This point is well worth considering and will be touched upon in the continuation of this article and in others which follow.

In addition to the cast iron, wood and steel pulleys already mentioned, there are several types of special pulleys which are used particularly as motor pulleys for driving machines or shafting. These will be taken up in a continuation of this article which will appear in an early issue. In addition this future article will contain some suggestions on the various methods which are used to obtain greater adhesion of the belt to the pulley, a discussion of the wastage due to slippage, as well as other important service considerations concerning the operation of pulleys in industrial works.

(EDITOR'S NOTE: Acknowledgment is made to the following concerns who have co-operated with the editors of INDUSTRIAL ENGINEER by supplying information and illustrations on pulleys and their application: American Pulley Co., Philadelphia, Pa.; Birkle Manufacturing Co., Chicago, Ill.; W. E. Caldwell Co., Louisville, Ky.; Chicago Pulley & Shafting Co., Chicago, Ill.; Composition Wood Products Co., Chicago, Ill.; Cork Insert Co., Boston, Mass.; Dodge Sales & Engineering Co., Mishawaka, Ind.; W. A. Jones Foundry & Machine Co., Chicago, Ill.; Ohio Valley Pulley Works, Maysville, Ky.; Pyott Foundry Co., Chicago, Ill.; Rockwood Manufacturing Co., Indianapolis, Ind.; T. B. Wood's Sons Co., Chambersburg, Pa.; and Saginaw Manufacturing Co., Saginaw, Mich.)



Some of The Points to Remember in The

Use and Maintenance of Safety Switches

That Are Manipulated by The Operators of Motor-Driven Machines in Industrial Works

By R. B. ANDERSON

Formerly Service Manager, Square D Company, Detroit, Mich.

Fig. 1—This installation, controlling a large milling machine, shows how an unfused switch is mounted ahead of the compensator when overload relays are used.

SAFETY switches are a direct result of the use of individual motor drives in industrial works, the need for such protection as will enable machine operators to start and stop the driving motors without danger to themselves or the equipment, and the elimination of unauthorized tampering with the parts of a motor starting switch. The installation of these switches has been speeded up by legislation and the regulations of State Factory Inspectors covering the protection of workers and by compensation laws which make accidents to the workers expensive.

The first safety switches were of the oil type. Later the iron-clad switch was built in England. Obtaining the rights to manufacture these switches in this country marked the beginning of safely connecting and disconnecting current in industry. Successive improvements have produced the present highly efficient types of the industrial control and motor starting switches which are built to meet the exact requirements of the duties they are intended to perform.

BECAUSE A safety switch is enclosed and made as near accident-proof as possible, many men responsible for maintenance forget that after all it is an operating mechanism and should be given inspections and attention of the same nature that is paid to the vital parts of any other system. In this article, Mr. Anderson takes up typical safety switch applications and discusses some of the factors that enable this type of switch to best carry out the fundamental purposes of its construction and use in the operation of industrial motors.

The first point to consider when installing these switches should be the rating. Not only will complete specifications of the requirements make it possible to supply the proper switch, but they will also assure conformity with the Underwriters' requirements and local inspection regulations. The accompanying wiring data, Table I, will assist in determining the rating and size of the fuse, wiring and conduits necessary from the size of the motor for which a switch is desired.

Most municipal and other regulations require that motors over 5 hp. shall be started by compensators. Furthermore, the National Electrical Code specifies that when compensators are used, a switch must be installed ahead of the compensator so that repairs and adjustments of the

latter may be made safely, as shown in Fig. 2. Table II gives the wiring specifications for safety switches when used as disconnect switches ahead of compensators. Also, in case overload relays are used (Fig. 1) unfused switches should be installed. Motors of less than 1 hp. which are usually single-phase, are operated by fused switches.

One of the latest improvements in motor starting switches, which are commonly used instead of compensators, for motors over 1 hp. and under 5 hp., is the single-throw motor starting switch. This switch enables the operator to start the motor with one operation, similar in manner to an ordinary switch and without opening the circuit when going from "starting" to "running" position. These switches have two sets of blades; the auxiliary blades, shunting the running fuses, are connected in line with the running blades.

When motors are started by motor starting switches it is usually required that fuses be installed ahead of the switch. In cases where the motor is started by the unfused blades of the motor starting switch, if this were not required the motor would have no protection at starting. If it is unnecessary, because of rulings, the service entrance switch will usually answer this purpose.

Many of the serious problems of mounting such as insulation and accessibility have been overcome by safety switches. As a result many such hopeless tangles as are shown in Fig. 4 have been replaced by convenient and neat appearing switches systematically arranged. Fig. 5 shows how the wiring and switches of the installation in Fig. 4 were rearranged in a special housing after a fire resulted from the crossed wires.

It is unnecessary to mount these switch units on insulating material since the jaws, terminals, clips, and so on, are assembled either on a slate, porcelain or other insulating base, according to the type of manufacture. The safety switch may be fastened to walls, machines, steel brackets, or any place that the box will fit without anything else but the bolts or framework necessary to mount the box. Formerly, special switchboards were constructed and if the switch itself were not mounted on insulated material often serious difficulties were encountered in obtaining the necessary nonconductive mountings.

Sometimes considerable difficulties are encountered with slate. This is one of the chief bases now in use, but it is rapidly being replaced by the composition base because the absorbed dampness and metallic veins often render slate conductive and consequently it becomes a poor insulator. Men responsible for main-

Fig. 2—Mounting when overload relays are used.

The code requires, "When auto starters are used a switch must be provided on the supply side of each auto starter." Here the compensator type of fused switch is shown ahead of the compensator. The compensator in this installation is not equipped with overload relays, so that this switch provides two sets of leads. one an unfused lead to take care of as heavier starting currtnt and a fused lead for running.

Fig. 3—Protecting the starting equipment from drippings.

This illustration shows how easily an installation can be made with safety switches. The switch and direct-current controller are mounted on columns supporting the ceiling, with conduits running from the floor. The hood shows one method of protecting the equipment from the surrounding conditions. This may be easily applied in any like circumstances.

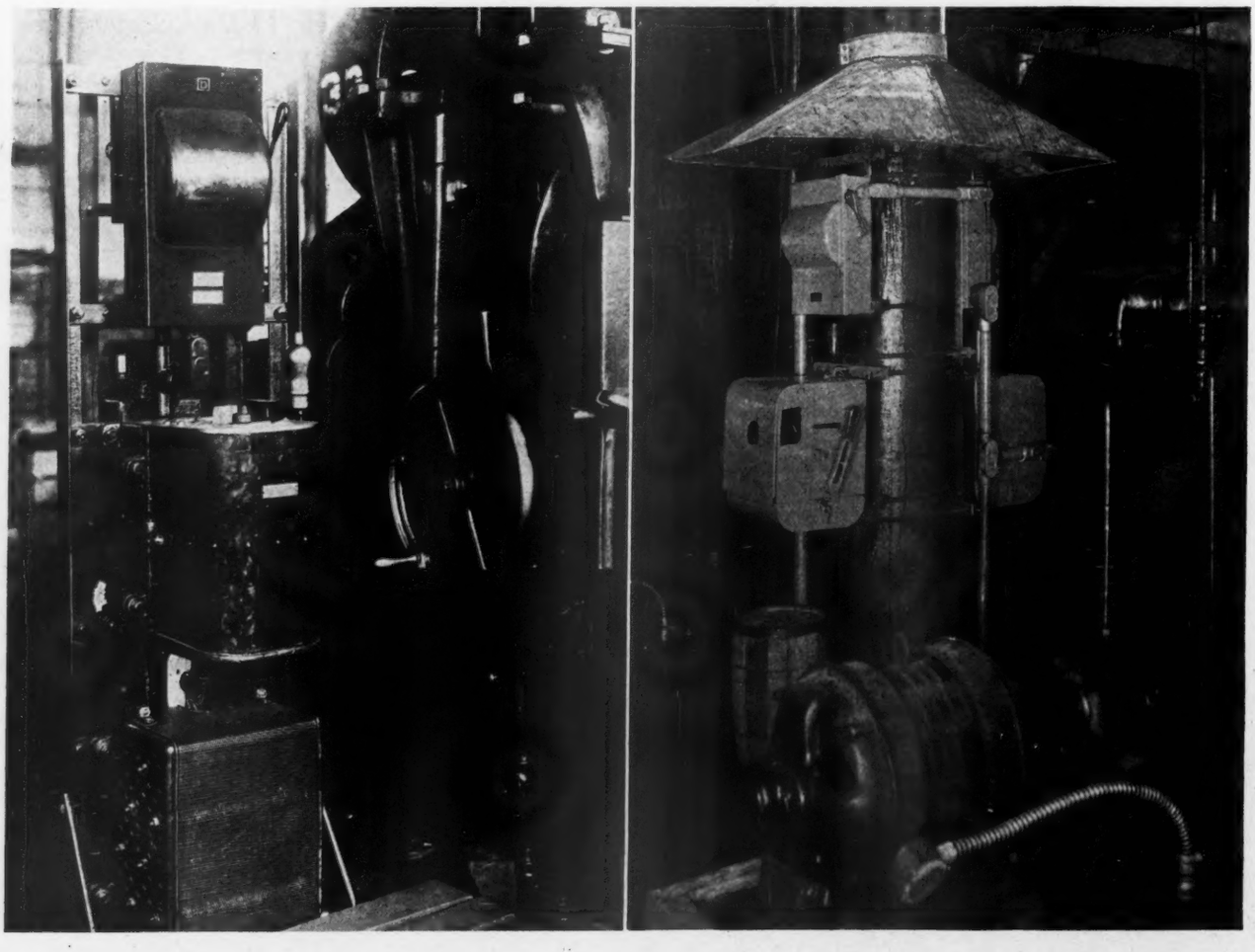


Table I—Wiring Data for Motor Starting Switches

H. P. of Motor	Voltage	Switch Amp. Rating	Approximate Full Load Current Amp.	Size of Starting Fuses Amp.	Size of Running Fuses Amp.	Size of Wire B & S. Gage	Size of Conduit for 3 Wires Inches
Three-Phase Motors							
1	110	30	6	15	10	8	1
	220	30	3	8	6	8	1
	440	30	1½	4	3	10	¾
2	110	30	12	30	20	8	1
	220	30	6	15	10	8	1
	440	30	3	8	6	8	1
3	110	30	18	40	25	8	1
	220	30	9	25	15	8	1
	440	30	4½	10	6	8	1
5	110	60	30	70	40	6	1¼
	220	30	15	35	20	6	1¼
	440	30	7½	15	10	8	1
*7½	110	60	42	80	60	4	1¼
	220	60	21	40	30	8	1
	440	30	10½	25	15	8	1
Two-Phase Motors							
1	110	30	5.2	15	10	....	1
	220	30	2.6	8	5	8	1
	440	30	1.3	4	3	8	1
2	110	30	10.4	25	20	8	1
	220	30	5.2	15	8	8	1
	440	30	2.6	8	5	8	1
3	110	30	15.6	40	25	8	1
	220	30	7.8	20	15	8	1
	440	30	3.9	10	7	8	1
5	110	60	26	65	45	6	1¼
	220	30	13	35	25	8	1
	440	30	6.5	20	12	8	1
*7½	110	60	36.4	90	60	4	1½
	220	30	18.2	45	30	8	1
	440	30	9.1	25	15	8	1
Single-Phase Motors							
2	110	30	24	60	30	4	1¼
	220	30	12	30	20	8	1

*NOTE—Power Stations' regulations sometimes require compensators with motors of 7½ horse power.

Table II—Wiring Data for Safety Switches

When Used as Disconnect Switches Ahead of Compensators

H. P. of Motor	Voltage	Switch Amp. Rating	Approximate Full Load Current Amp.	Size of Starting Fuses Amp.	Size of Running Fuses Amp.	Size of Wire B. & S. Gage	Size of Conduit for 4 Wires Inches
7½	100	60	36.4	90	60	4	1½
	220	30	18.2	45	30	8	1
	440	30	9.1	25	15	8	1
10	110	110	48.5	125	80	3	1½
	220	60	24.2	60	40	6	1¼
	440	30	12.1	30	20	8	1
15	110	200	73.0	200	125	0	2
	220	60	36.4	90	60	4	1½
	440	30	18.2	45	30	8	1
20	110	200	90	200	150	00	2½
	220	100	45	100	75	3	1½
	440	60	22.5	45	35	8	1
30	110	400	135	300	225	0000	2½
	220	100	67.5	175	100	1	2
	440	60	33.8	85	55	5	1¼
40	220	200	91	225	150	00	2½
	440	100	45.5	100	75	3	1½
50	220	200	113	275	200	200,000	2½
	440	100	57.5	150	95	1	2
75	220	400	159	400	250	300,000	3
	440	200	79.5	200	125	0	2
100	220	400	212	525	350	500,000	3½
	440	200	106	250	175	000	2½
150	440	400	159	400	250	300,000	3
200	440	400	204	525	350	500,000	3½

Tables I and II—Wiring and other important specifications to be considered when installing safety switches as a part of the motor control in industrial works.

To insure compliance with regulations, these specifications should be considered before making any installations of safety switches, either as motor starters or as disconnect switches ahead of compensators. In addition, due to the variance in state and municipal regulations, it is well to investigate the local requirements for the factors listed here and particularly for the size of the box as some local regulations specify a larger box than is ordinarily used and provided by the manufacturer except on special order.

tenance can feel safe, however, with safety switches with slate bases since every safety switch is rigidly inspected before leaving the factory.

It is usually advantageous to so mount the safety switch that the machine operator can reach it easily from his working position. This is particularly true of machines which are operated intermittently, as tool grinders which are turned on and off frequently. In addition, on individual drives it is often the practice to provide a place for installing the starting switch as a part of the mounting for the motor as generally only a small additional bracket or brace is necessary. It may be installed anywhere, however, and connected to the motor by conduit carried along the floor or on the ceiling. Dropping lines of conduit from the ceiling is generally preferable unless provision is made for running the lines underneath the floor, as it does not interfere with trucking and yet is easily accessible.

MOUNTING SAFETY SWITCHES

Accessibility is the chief requisite in mounting switches. Of course, like all other devices where parts are screwed or bolted together, safety switches are subject to loosening by vibration, so that where accessibility is not sacrificed switches subjected to vibration should be mounted separately from the machine. This may be easily done by mounting on a pipe framework or on a boardback on an angle-iron frame which answers these purposes well and usually can be conveniently located. Where it is necessary to mount the switch on machines of more than ordinary vibration careful inspection of the bolts and screws, with the other parts should be maintained. However, safety switches have stood the vibrations of punch presses and other heavy machines for several years without any apparent effect.

Individual motor driven machines can be controlled readily by switches mounted on piping with hook bolts and conduits from the ceiling as in Figs. 3 and 7. End plates with vari-

ous sizes of conduit knockouts for conduit wiring, or slotted to accommodate the numerous wires in compensator or "star delta" connections, or "open wiring" with various size holes in porcelain bushings for individual wires, can be obtained to facilitate easy connections.

Ample wiring space is usually provided within the box to accommodate most any need. It is quite natural that as switches increase in rating, so do their wiring and their wiring-space requirements. The switches of 200-amp. rating and up are usually connected with heavily insulated wire so that plenty of space is provided to bend this wire into position without cramping or harming the wire itself. Some local requirements insist on larger boxes than others so that on installing switches the city or local inspector should be consulted not only for the size of the switch box but also for arrangement of equipment, rating and other regulations.

Care should be taken in grounding the switch box for should a short circuit be created in a switch whose box was not grounded or poorly grounded, the results might be serious. The best ground for a switch box is from the box to a water pipe; however, when this means is inaccessible, grounds can be made on the conduit. In fact the conduit grounds the box as soon as it is attached to the box, but this method is not as satisfactory as a water pipe ground, since it is possible for the conduit to become loosened from the box, or if flexible, to separate, thereby removing the connection. To overcome poor grounds some maintenance men have, especially on ground floors, driven pipes into the ground plugged at one end and filled with water. This makes a good ground, but the best, of course, is the water pipe. Oftttimes when this method is used two or three pipes are driven into the ground and clamped together in order to cover a required area.

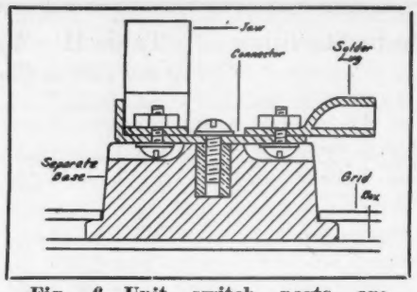


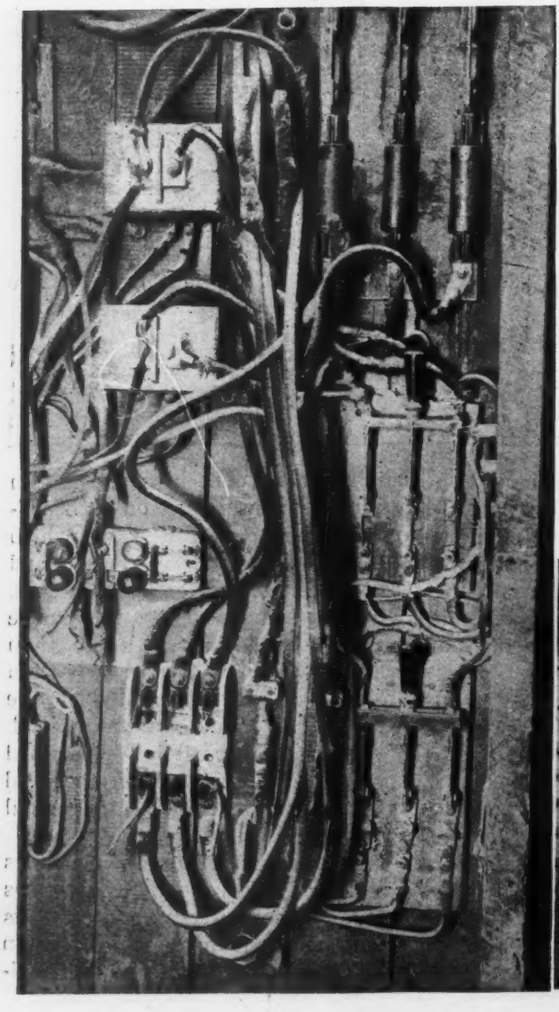
Fig. 6—Unit switch parts are mounted on individual insulated bases.

Formerly the working parts of this type of switch were mounted and sealed on a large slate base. Now the working units are mounted on individual composition bases. Loosening the center screw permits the removal of the entire unit for replacement or adjustments.

Much consideration should be given the position the operator must occupy when using a switch and a dry, well-insulated position should be selected. All boxes should be grounded and lugs are provided for the purpose. On an installation where there is considerable dampness and moisture, a good ground will probably prevent an accident even though the operator is standing on highly conductive or wet flooring. Where possible an insulated position should be obtained, such as a rubber mat or a rubber glove over the handle, but there have been cases where even in a highly conductive position, but because of the protection afforded by a good ground, operators have been unharmed in case of a short.

Recently a switch used in connection with a novelty at an amusement park to connect and disconnect current which supplied small cars run by motors on a steel floor from a trolley net overhead, "blew" with considerable fire and smoke. The switch had been in use for a long time and because of uninformed operators the insulated cross-bar tubes (see Fig. 9) were allowed to wear thereby causing a short circuit with the box, but because of a good ground the operator was unharmed. This accident could have been avoided had the switch been inspected and the worn parts replaced.

It would be rather difficult to set a standard ruling for the inspection of safety switches in all plants since



Figs. 4 and 5—A hopeless tangle of wires and how it was rearranged after burning itself out.

It is not necessary to point out the danger and difficulty an operator experiences with such an installation as that shown at the left. It is not strange that a fire was actually caused by this tangle. The installation shown below replaced the one at the left. Note the simplicity of mounting and how safely and conveniently the conduits are installed.

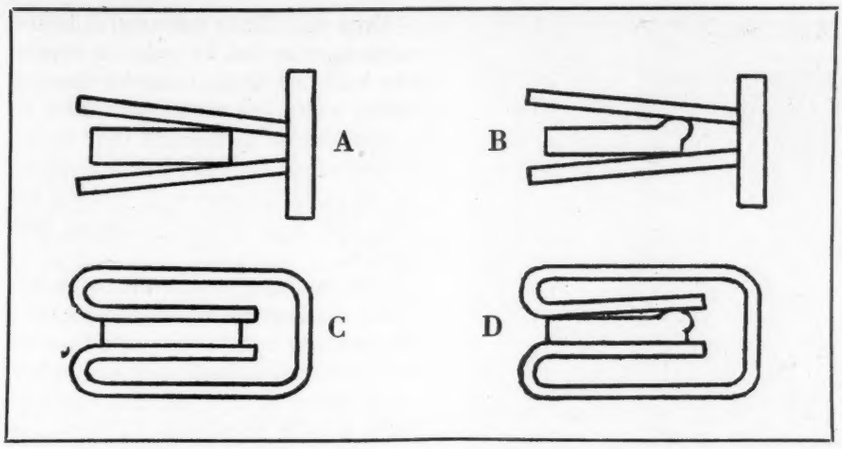


Fig. 8—The action of blistered blades on milled and multi-spring switch jaws.

A. This shows a blade inserted in the straight milled jaw. Contact is not made over the entire surface of the blade unless it is an exact fit. *B* shows a poor contact made when a blistered blade is inserted in a straight milled jaw. Multi-spring jaws (*C*) conform to the entire surface of the blade, however, and give fair contact, as shown at *D*, even though it is blistered.

the conditions under which they are employed vary almost as much as do the industries they serve. If a switch is subjected to constant use, that is, repeatedly being thrown "off" and "on," it would naturally be more likely to need closer attention than one which is used possibly only once or twice a day. Vibration, corrosive fumes, dust and any other condition which might affect the switch should be considered in regulating the severity of the inspections and their frequency.

With the operating mechanism enclosed as is this, inspection is too often neglected. The moving parts, however, need inspection just as they do in any other mechanism. Because one cannot see the moving parts is no reason for assuming that they will go on functioning forever without attention. Most likely nothing will happen, but the only way to be sure is to know.

Inspection Routine in One Plant

In one steel plant every safety switch is inspected regularly at two-week intervals. Here the electrician on his inspection trip carries an insulated screwdriver and pliers, an oil can, a can of light grease of about the consistency of vaseline, a bucket of black paint, a brush and sandpaper. After unlocking the switch and opening it up, the electrician tries out each screw holding the connector and switch jaw to the unit composition base. He then tests the nuts holding the soldered connector lugs to this unit. Although these screws and nuts have lock washers and are not likely to work loose easily it has been found best to test out each time because in the interval between tests it may have been worked on and not tightened up securely. Practically all loosening of these parts, however, can be traced to a failure to make them tight.

On machines which are used intermittently and so liable to rough up slightly on the blades or jaws because they are turned on or off frequently, the inspector smoothes these up with the sandpaper. He then greases the blades and jaws, puts a drop of oil on each switch hinge jaw, and throws the switch on and off, where possible, to see how it operates. Because of rough usage and the atmosphere surrounding some switches the inspector glances over the switch box, sandpapers any spot where the enamel has been knocked off, and touches it up with black paint. This may be more frequent inspection than may be absolutely necessary in most work; however, regular inspections are the cheapest form of maintenance.

It has been found that finely powdered substances, when subjected to heat, are at times explosive. While the switch boxes are not entirely dust proof, by surrounding these boxes with a tight wooden cabinet,

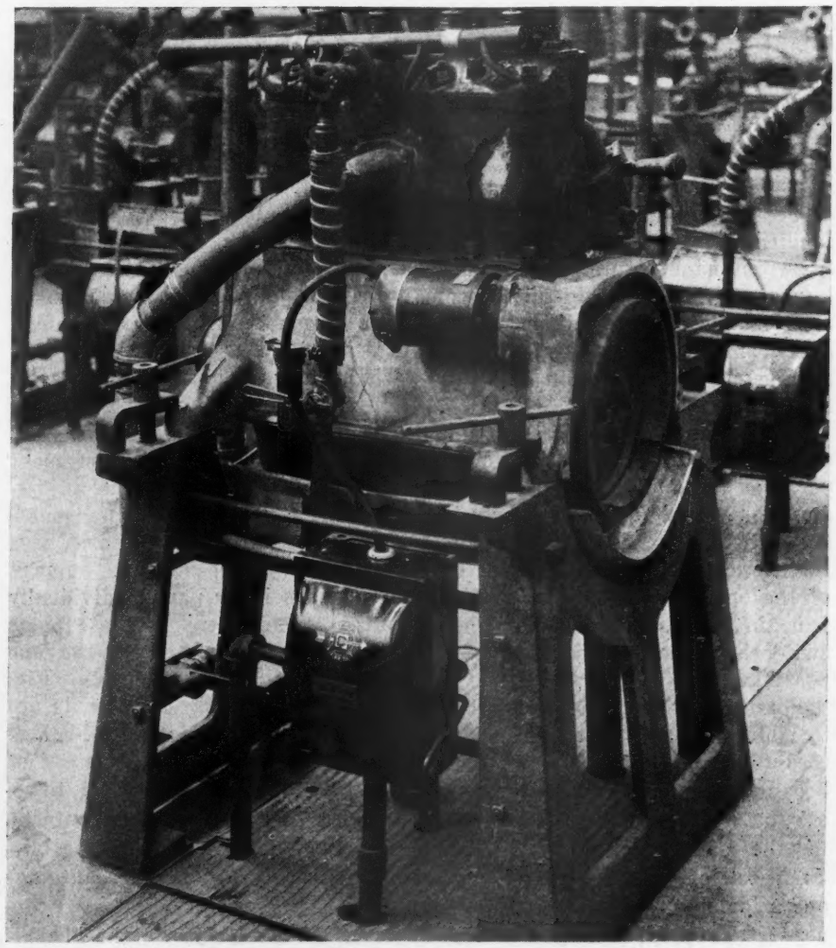


Fig. 7—This starting switch is easily accessible, yet out of the way.

This shows a motor starting switch supported by piping from the floor. The starting lever is shown in neutral. Pushing down starts the motor on the line and pushing up connects the blades with the fuse for the running position.

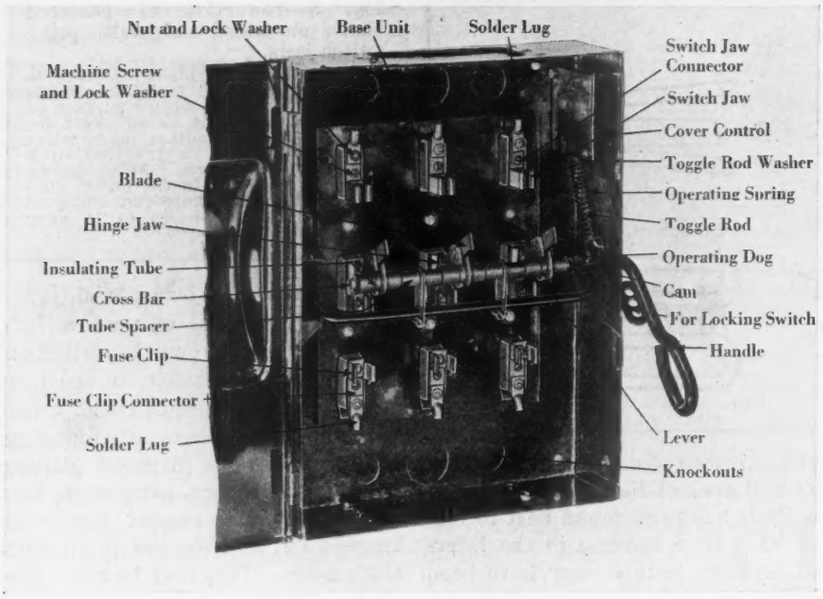


Fig. 9—Diagram of moving and stationary parts of one type of safety switch.

they can be made almost dust proof. Even then arcing may be dangerous, so that in such cases the entire interior of the switch should be closely watched and cleaned often.

All parts of the switch should be inspected. However, the most important parts are the ground, the cross-bar insulation and the jaws. Parts are interchangeable and may be renewed so that under ordinary conditions and with interchangeable parts a safety switch will last a long time. The boxes of either the iron-clad or the sheet-steel types are heavily enameled so that a great deal of protection is given against steam or acid fumes under extraordinary conditions. Few, if any, of the safety switch manufacturers are producing an absolutely acid-fume-proof switch. Nor can the ordinary safety switch meet the requirements for switches to be installed in the vicinity of gasoline fumes.

The extent of abuse that a safety switch will stand before failing to perform its duties properly is remarkable. Few plants regularly inspect their switches, and the manufacturers, primarily with the safety of the operator and of the mechanism in view, have made these switches as nearly accident-proof as possible.

Possibly the greatest abuse both to motor starting switches and motors takes place when an operator does not permit the motor to accelerate to full speed when the switch is in the starting position. About twenty seconds is required for this operation, yet some operators change as fast as they shift gears on an automobile, in both cases within a few seconds. Quite often fuses are blown if such is the case, or excessive heating and blistering follows. Switches are now being developed to automatically control this change by a thermo-control.

Some of the Abuses of Safety Switches

Blistered jaws and blades are often caused by not throwing the blades far enough into the jaws and because of this abuse some switches not equipped with quick make devices have positive make attachments. This arrangement assures a positive make or no make at all.

Fuses removed with pliers, grounds not made, box covers left open, switches operated with worn insulation are abuses of which a machine operator should not be guilty.

The construction of the equipment is such as to facilitate the adjustment and renewal of interchangeable parts. For example, unit bases have replaced larger bases and support the various inner parts individually so that replacement of these parts can be made in one-tenth of the time required with the larger bases. Fig. 6 shows how simply these parts are connected. In addition, multi-spring jaws, Fig. 8 *C*, are used instead of straight milled jaws, Fig. 8 *A*, to reduce the possibility of poor contacts, even though the blade may be blistered (Fig. 8 *B* and *D*) because the multi-spring jaw (Fig. 8 *D*) conforms to the shape of the blade.

Even with these features, it is absolutely essential, in order to obtain the best and longest service from a safety switch, to remember that it is a mechanical device and that it requires attention. Regular inspection of all parts not only will prolong its life, but also obtain maximum efficiency.

The moving parts, particularly, require close attention, and especially the contact points. If jaws become too widely separated they can easily be restored to their natural position with a pair of pliers. If they are found to overheat, emery cloth rubbed on the inside of the jaw and over the blade quite often relieves this condition. Manufacturers use vaseline on the tip of the blades to insure free motion within the jaws. Occasional renewing of this application will assist the motion.

Most switches are now equipped with quick make and break features, that is, springs contrived to throw the blades into the jaws or release them from the jaws quickly, so as to prevent destructive arcing; however, when switches are used that do not include this feature, the operator should be instructed to make the actual connection or disconnection of the blade contacts by throwing on or pulling off the lever quickly, so as to maintain the same precaution.

Porcelain protective covers have recently been designed to slip over jaws, leaving a slot for the blades, thereby further assisting the other devices to prevent arcing and especially to cover the live terminals.

Cover control devices have become popular because they prevent opening the switch when it is in the "on" position, without a key, which provides for inspection by authorized persons without throwing the switch off and interfering with production. Provision for locking the switch in the "off" position is also desirable, as it assures safety to both men and equipment when a machine is stopped for adjustment or repairs.

It is necessary to provide the same order of care for a safety switch as for other machinery. The parts that are subject to the greatest wear can be renewed for a few cents, yet many switches must be replaced completely when the renewal of a small part could have prevented a short-circuit, or just a little attention in adjustments would overcome the possibility of early replacement.

ROTORS OF slip-ring induction motors are wound in almost the same way as stators. The slight differences from the stator winding are, however, of vital importance. In this article Mr. Roe tells just what these differences are. He gives figures and diagrams which explain just how the connections should be made on any wound rotor. Of special value is a simplified kind of diagram which may be applied to a stator or any other kind of winding. Mr. Roe is now shop superintendent in the Detroit branch of the Westinghouse service department.

Details by A. C. Roe on

Wound Rotor Connections

When Both Lap and Wave Types of Windings Are Used

This illustration shows end and slot insulation in place and the winder inserting the coils in the rotor of a slip-ring induction motor.

WOUND rotors of alternating-current induction motors are wound in almost the same way as stators. The main differences are in the arrangement of the leads, jumpers, and so on, and also that the rotor winding is in all cases three-phase, even in a two-phase motor. The type of coils used are the same as those employed for stator windings. These coils are described in articles by the writer in the INDUSTRIAL ENGINEER for April, June and July, 1922.

Some general features of the method of connecting wound rotors will help to explain the details which are given later in this article. In the first place, the coils are wound, shaped and put on the rotor so that the leads of each coil are brought out on the under side of the winding, or the side nearest to the shaft as shown in *S* of Fig. 1. The long cells (slot sections) of the coils are put in the top of the slot in the same way as the coils of a direct-current armature. The leads are brought out 120 mechanical degrees apart, if possible. This is done so that there will be the shortest possible length of cable in the leads that go to the terminals on the slip rings which are also spaced 120 deg. apart. Furthermore, the connections to the star jumper are spaced 120 deg. apart so that the entire winding is in mechanical balance. Either lap windings or wave windings may be employed, though the wave windings are much commoner. The lap windings will be taken up first in this article.

DATA TO BE TAKEN BEFORE STRIPPING ROTOR

When stripping a rotor, sufficient data should be taken to enable the winder to get the new winding back in the proper manner. For a lap winding he should put down the number of coils and slots, the size of wire, the pitch of the coil, the turns per coil, the number of wires in parallel per coil, the type of connection, and so on. It is also a good plan to number the slots, using a piece of chalk for temporary marking. Start by calling a slot from which a lead is brought out, No. 1. Number the slots in rotation. Then record the slot to which each lead connects and the slots to which the star point is connected (if star-connected). For wave windings even more data may be necessary. Under the drawings of wave windings in Figs. 2 and 6 there is indicated the various items of data which should be taken for the kinds of wave windings shown.

For lap-wound coils the short type of jumper is used as shown in *R* and

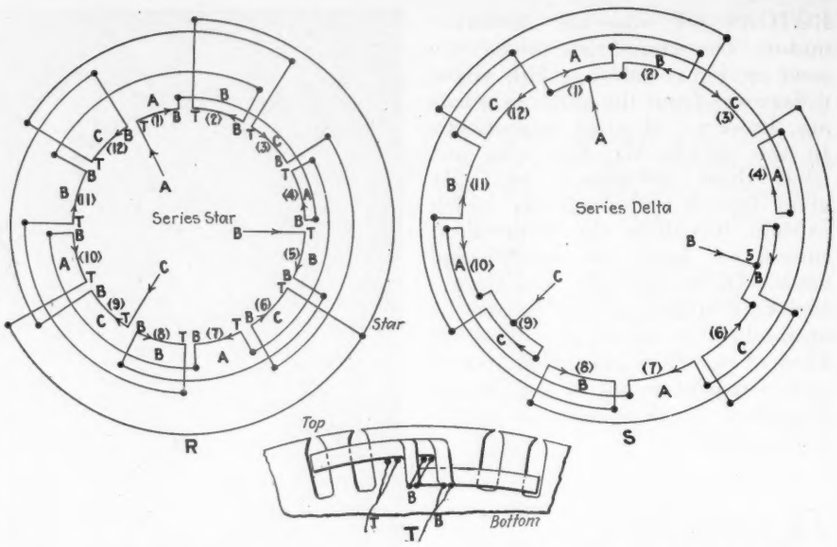


Fig. 1.—Connections for lap-wound rotors.
A lap-wound rotor has the leads brought out 120 deg. apart around the rotor. Also, all connections are made on the inside (on the shaft side) as shown at *T*. The diagrams are for a four-pole three-phase winding, with groups connected top-to-top and bottom-to-bottom with short jumpers.

T of Fig. 1. This means that each jumper runs from the top of one coil to the top of another, or from the bottom of one coil to the bottom of another. In Fig. 1 the methods of bringing out the leads are shown. Both of the drawings are for a four-pole motor. At *R* is a series-star connection with the leads and the star connections brought out 120 deg. apart. Drawing *S* shows the same winding connected in series-delta. This gives a better mechanical balance than the star winding. In the diagrams of Fig. 1 each pole phase group is given a number reading from left to right or clockwise. The letters *T* and *B* indicate which ends of the group are top and bottom. This is explained by the drawing at *S*. This drawing shows a group of two coils. The leads coming out of the top coil (the one in the top section of a slot) is called the top lead of the group. The lead from the bottom coil is the bottom lead of the group.

In order to get these leads connected at the proper places, the accompanying table can be consulted. The table shows to which groups the leads should be connected. It covers both series-star and series-delta windings and applies to motors having from four to twenty-four poles. It will be noticed that the leads are always connected to the top of the groups indicated in the table.

Table I—Series-Star and Series-Delta Connections for Lap-Wound Rotors

No. of Poles	No. of Pole Phase Groups	Series-Star Connection						Series-Delta Connection		
		Leads From Slip-Ring Terminal to (Top) of Group Number Below			Star Connections From (Top) of Group Number Below			To Slip-Ring Terminal (A) Connect Tops of Groups Numbers	To Slip-Ring Terminal (B) Connect Tops of Groups Numbers	To Slip-Ring Terminal (C) Connect Tops of Groups Numbers
		A	B	C	A	B	C	A	B	C
4	12	1	5	9	10	2	6	1 and 2	5 and 6	9 and 10
6	18	1	8	12	16	5	9	1 and 5	8 and 9	12 and 16
8	24	1	9	17	22	6	14	1 and 6	9 and 14	17 and 22
10	30	1	11	21	28	8	18	1 and 8	11 and 18	21 and 28
12	36	1	14	24	34	11	21	1 and 11	14 and 21	24 and 34
14	42	1	15	29	40	12	26	1 and 12	15 and 26	29 and 40
16	48	1	17	33	46	14	30	1 and 14	17 and 30	23 and 46
18	54	1	20	36	51	17	33	1 and 17	20 and 33	36 and 51
20	60	1	21	41	57	18	38	1 and 18	21 and 38	41 and 57
22	66	1	23	45	63	20	42	1 and 20	23 and 42	45 and 63
24	72	1	26	48	69	23	45	1 and 23	26 and 45	48 and 69

NOTE—This table shows to which groups the slip-rings and star points should be connected. The data given are for lap windings with short jumpers (top-to-top and bottom-to-bottom connections). It applies to three-phase windings having from four to twenty-four poles.

Wave Windings for Rotors

The commonest type of winding met with in rotor repairing is the wave winding. There are two kinds of wave windings, the first being that in which the number of slots is a multiple of the number of poles and phases. In other words, the number of slots divided by (the number of poles multiplied by the number of phases) equals a whole number. Fig. 2 gives two examples of this type of wave winding. The other type is the ordinary direct-current wave winding which does not conform to this rule. This type of winding will be treated later on, but for the present the type first mentioned will be discussed.

Before discussing the windings it is well to review the definitions of a few terms which are used. The first of these is the winding pitch, W.P., which is equal to the number of coils divided by the number of pairs of poles. The second is the back pitch, B.P., which equals the winding pitch divided by two. Finally, there is the front pitch, F.P., which equals the winding pitch minus the back pitch.

The windings are usually divided into six sections which are then interconnected to form the correct three-phase relation. The method in which a winding of the first class is divided into six sections is shown in Fig. 2. There are two of these sections to each one of the phases. The first of the sections in the windings of Fig. 2 is formed by a series of coils which passes twice around the armature in one direction. Then

a short jumper is run to the beginning of the other section. This consists of a series of coils passing twice around the armature in the opposite direction. As each phase has two sections corresponding to these there are in all six sections. In any rotor the number of coils per section is equal to the total number of coils divided by six. For Fig. 2 there are twenty-four divided by six, or four coils per section. The starting point for each section in this winding will be eight coils apart, which is found by dividing twenty-four coils by three. In other words, the top of slot Nos. 1, 9 and 17 will hold the leads. Starting at slot No. 1, we pass through four coils, or one section, in a clockwise direction, and then pick up four more coils in the opposite direction. The heavy lines represent the two sections which are in one phase. These sections lie in the following slots, 1, 7, 13, 19, 24, 6, 12, and 18; through a reversing jumper to slots 24, 18, 12, 6, 1, 19, 13, 7, and out to the star connection. It will be noticed that every back pitch equals six slots as: 1 to 7, 13 to 19, 24 to 6, 12 to 18. The front pitch started out equal to six slots, but just before completing one passage around the winding, the last pitch covered only five slots. In

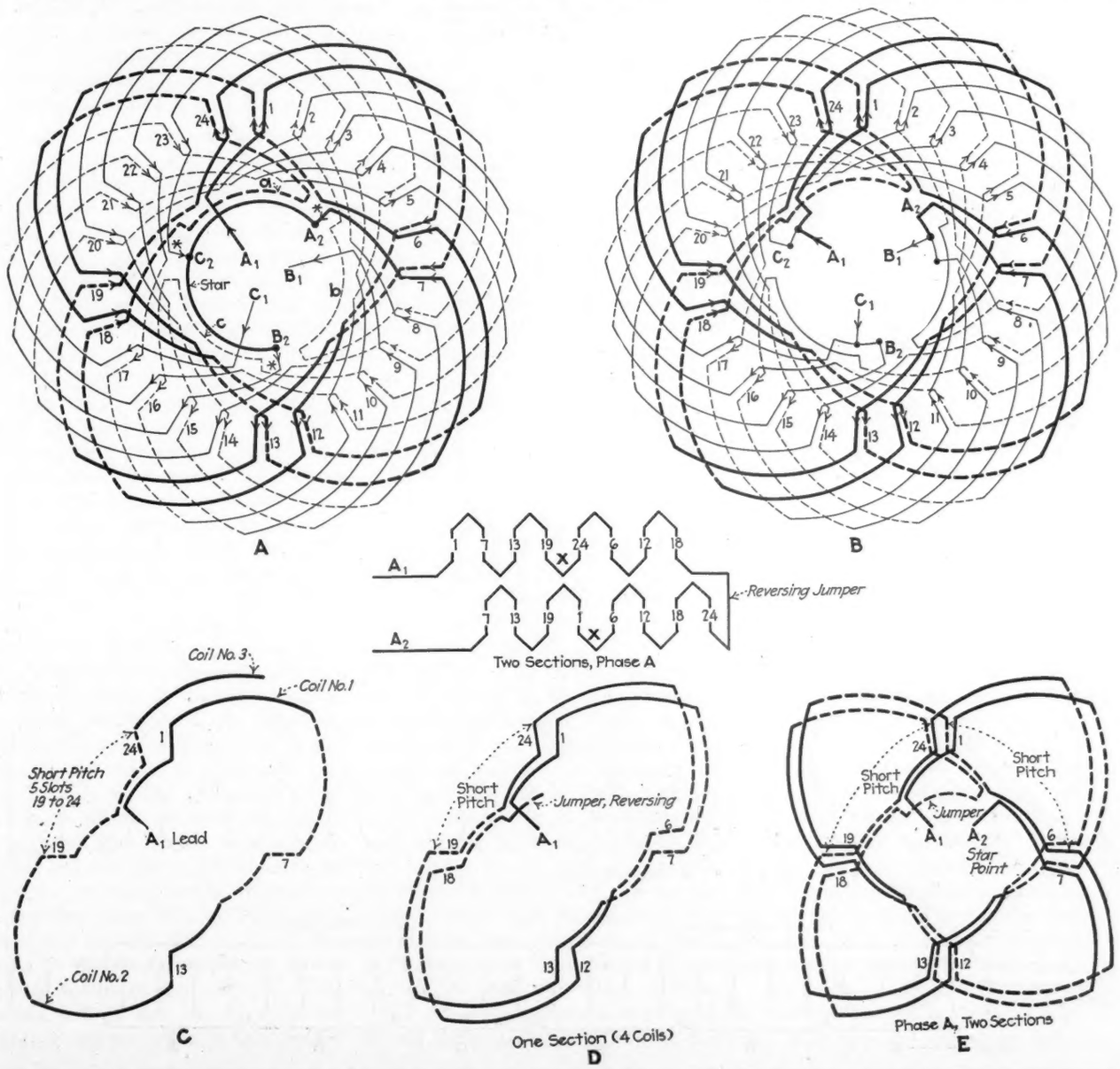
Fig. 2—Wound rotor with number of slots a multiple of number of poles and phases.

This is a three-phase, four-pole wave winding having 24 slots and coils. The winding pitch is 1 and 13; front pitch, 1 and 7, and back pitch, 1 and 7. Drawing *A* shows a series-star connection and drawing *B* shows a series-delta connection. Drawings *C*, *D* and *E* explain the details of one phase. At *C* two coils are in place. This completes the series once around the armature. When coil No. 3 is started the front pitch is shortened from six slots to five slots making coil No. 3 start in slot No. 24. In *D* four coils are in place. This forms one section of which there are six, two per phase. The next section starts in the bottom of slot 24 and passes around in counter-clockwise direction. It is connected to the first section by the reversing jumper shown in *D*. Four coils are put on for this section as shown in *E*. These eight coils constitute the entire *A* phase. For each of these windings the front connections are as follows:

Front Connections

Bottom	to top	Bottom	to top
1	6	13	19
3	8	14	20
4	10	15	21
5	11	17	22
6	12	19	24
7	13	20	2
9	14	21	3
11	16	22	4
12	18	23	5

The reversing jumpers connect together the bottoms of slots 24 and 18, 16 and 10, 8 and 2. For the star connection (*A*) the leads connect to the top of slots 1, 9 and 17. The star connections go to the top of slots 7, 15 and 23. For the delta connection (*B*) the leads go to the tops of slots 1 and 23, 7 and 9, 15 and 17.



other words, it was 19 to 24 as shown in *C* of Fig. 2. The reason for this is that if a full pitch of six slots were used at this point, the start of the next coil would be in slot No. 1 which would form a complete short circuit around the armature. To eliminate this, the pitch is shortened to five slots and the winding is continued again around the rotor. In going around the rotor for the second time, after slot 18 is reached a short jumper is put on and the next coil is put in the bottom of slot 24 as shown in *D*. The following coils are passed through in a counter clockwise direction around the rotor. After this series passes around the rotor to slot No. 6 a short front pitch is used to connect to the coil in slot No. 1. After this the coils are passed through with front and back pitches equal to six slots, ending with the coil in the top of slot 7 from which a lead is taken out to the star point as at *E* in Fig. 2. This completes the two sections which make up one phase.

As shown in *E*, the front pitches of the first section (shown in *D*) are at the opposite ends of the same slots in which the back pitches of the other sections lie.

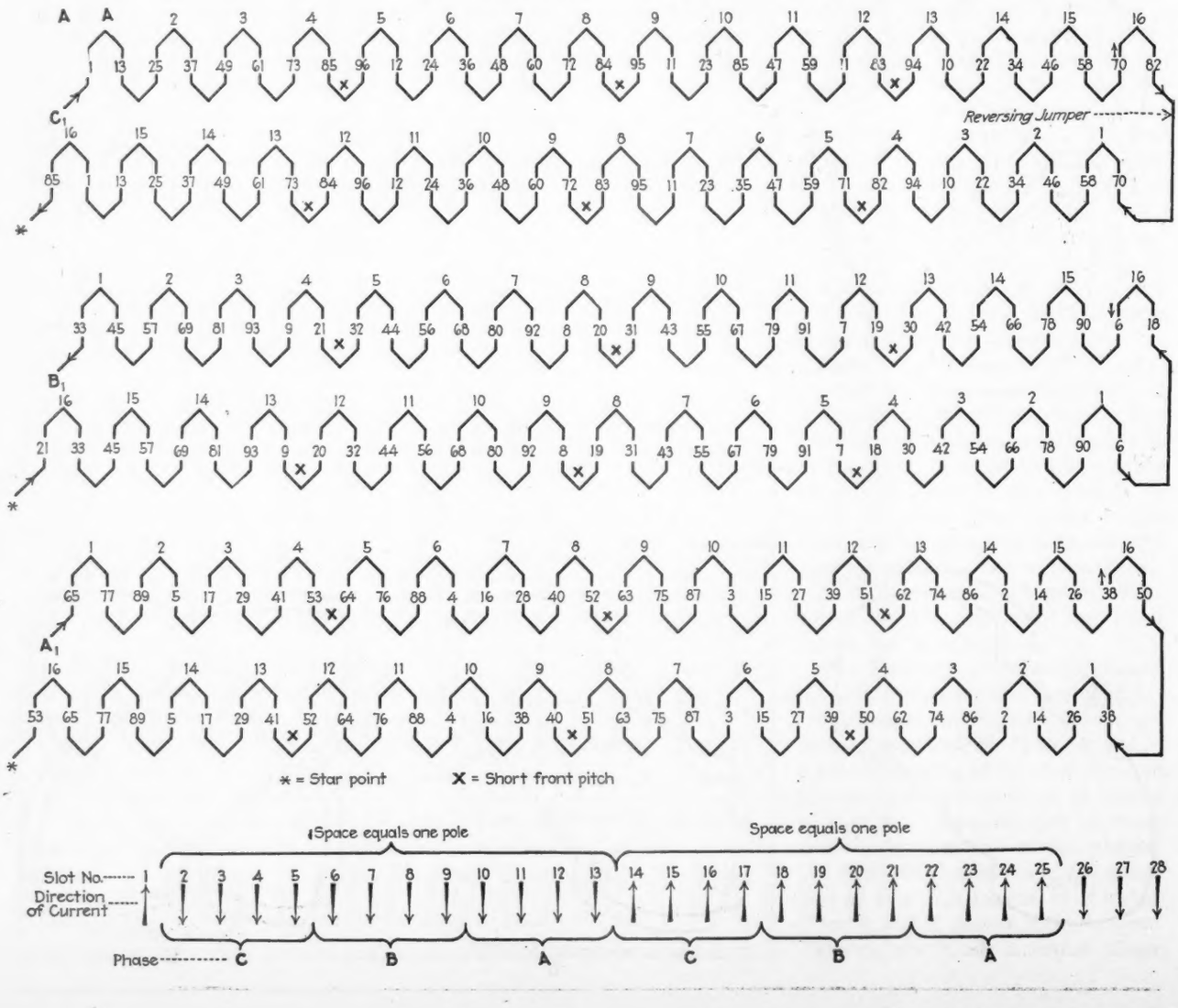
This short pitch at the points mentioned in the preceding paragraph is what makes this type of winding different from the ordinary direct-current wave winding. In ordinary direct-current windings a series of coils encircles the rotor and ends in a slot one ahead or one behind the slot in which it started. All of the coil pitches are equal. However, with a number of slots divisible by the number of poles, if all of the coil pitches were equal the last coil would connect to the first coil, which would result in a short circuit. It is for this reason that the front pitch is decreased by one slot after passing around the rotor once. On account of this arrangement a rotor winding of this type is nearly always retrogressive.

Fig. 3—A simple way of laying out a winding.

A drawing of this kind is easier to make and simpler to understand than a drawing like those in Fig. 2. This drawing represents a retrogressive right-hand wave winding connected in series-star for a wound rotor. There are 96 slots and coils, eight poles and three phases. The winding pitch is 94÷4=24 or 1 and 25. The front and back pitch are each 1 and 13. The leads connect to the top of slots 1, 33 and 65. There are six groups having sixteen coils each. The lower part of this figure shows how to check the polarity of the winding. The arrows represent the direction of current flow in the slots. As there are twelve slots per pole in this rotor, the current in twelve adjacent slots should flow in one direction and the current in the next twelve should flow in the opposite direction, etc. This type of drawing can also be applied to windings which have more than two coil sides per slot as shown in Fig. 4.

Simple Method of Laying Out a Wave Winding

Although the kind of diagram shown in Fig. 2 is commonly used, there is a much simpler kind which can be employed for checking and developing the winding. This type of diagram can be applied to rotor, stator or armature windings. It can be made more quickly than the drawing shown in Fig. 2 and it is better



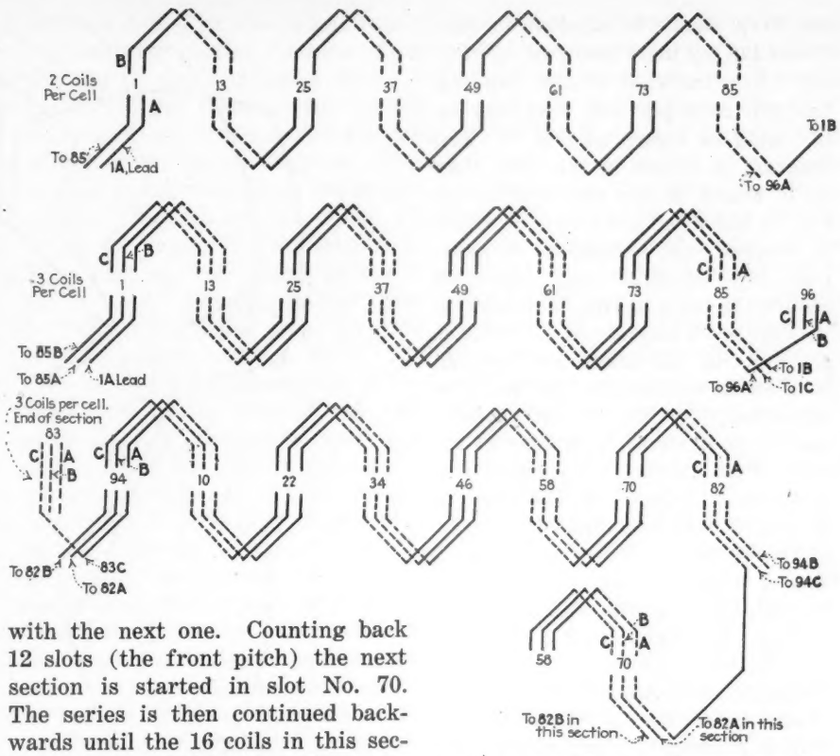


Fig. 4—Diagram to show more than one coil per cell.

This is similar to the diagram in Fig. 3 except that here more than one coil is shown per cell. The first two drawings represent the start of the *A* phase. The bottom diagram shows how the jumper is connected between the two sections of the *A* phase. The inside coil (*C*) at the end of the first section is connected by the reversing jumper to the outside coil (*A*) of the second section.

for use in determining where to open a winding for changes in voltage, and so forth. This is the type of diagram shown in Fig. 3. It is not difficult to lay out as will be seen by the following example: The diagram in Fig. 3 is for a rotor with 96 slots and eight poles. It is to be connected in a right-hand wave retrogressive winding in series-star. The winding pitch is first determined. It is equal to the number of slots divided by the number of pairs of poles, or 96÷4=24, a pitch of 1 and 25. Then the back pitch equals one-half of 24 which is 12 slots, or a pitch of 1 and 13. The front pitch equals 24 minus 12 or again a pitch of 1 and 13. Next find the slots from which the leads are brought out. For balanced spacing the leads are brought out 120 mechanical degrees apart or one-third the distance around the rotor. As 96÷3=32, the leads will be brought out of the top of slots 1, 33 and 65. In a rotor winding of this kind there will be 96÷6, or 16 coils in each section. There will be 32 coils for each phase.

After these figures are known the diagram can be made. A piece of cross-section paper is suitable for drawing such a diagram. As shown in the drawing, the coils are represented as being laid out flat in series. The coils are put down in the order in which they come in the series as coil No. 1, 2, 3, etc. Vertical lines are drawn to represent the slots in which the coils lie and these lines are numbered according to the slot number. Starting with the *C* phase we have one side of coil No. 1 in slot No. 1 and the other side in slot No. 13, as the back pitch is 1 and 13. Then adding the front pitch (12) to 13 we get slot No. 25 in which the second coil is connected. Then add the back pitch of 12 to 25 and we get slot No. 37 which contains the other side of No. 2 coil. Continue in this way until all the coils in one section are put down, which in this case is 16 coils. This series ends in slot No. 82. The reversing jumper connects this section with the next one. Counting back 12 slots (the front pitch) the next section is started in slot No. 70. The series is then continued backwards until the 16 coils in this section are passed through. These two sections form the entire *C* phase.

In this way, the coils in slots 1, 13, 25, 37, 49, 61, 73, 85, are connected, stepping twelve slots ahead in every case until the rotor is almost circled once and it is time to make the last front pitch. Then before starting the second series around the rotor, this front pitch will decrease by one so that the next coil connects to the coil in slot No. 96. The place where this short pitch occurs is shown by the small dark x. As will be seen, this occurs in the *C* phase between coils 4 and 5, 8 and 9, 12 and 13, on passing around both clockwise and, on the return, counter clockwise. After the *C* phase is laid out in this manner, then the *B* phase is started in slot 33. After this phase is complete then the *A* phase is started in slot 65.

It is easy to check the correctness of polarity of this winding as shown in the lower drawing of Fig. 3. To do this, first put arrows on the three phases to indicate the direction of the current. The arrows on the *A* and *C* leads should go into the windings while those on the *B* lead should come out. In any case, two should go in one direction and one in the other. After the direction of the current is thus indicated, to check the polarity find the direction of the current in each slot taken in rotation around the armature. As shown in the lower drawing of Fig. 3, the first slot is No. 1. Consulting the six sections above, it is seen that the current in slot No. 1 goes upward. This slot No. 1 is found in the drawing for the *A* phase. Then slot No. 2 is found in the drawing for the *B* phase and it is seen that the current goes downward. By means of arrows as shown, placed side by side, these currents are indicated. Following on through it is found that the currents in 3, 4 and 5 (all of which are in the *C* phase) travel downward. Likewise the currents in 6, 7, 8 and 9 which are in the *B* phase, travel downward. Likewise, 10, 11, 12 and 13 in the *A* phase travel downward. This gives a total of twelve slots side by side in all of which the current travels in one direction. These twelve slots equal the distance covered by one pole, as there are 96 slots and 8 poles. Passing on from slot No. 14 to slot No. 25 we have twelve more slots in which the current flows upward. Continuing in this way entirely around the armature, we should have first twelve slots with downward current, then twelve slots with upward current, occurring alternately. If the connections are such that all of the arrows under the space of one pole do not point in the same direction, then something is wrong and a check should be made.

While the drawing in Fig. 3 is for a machine having a single coil per cell, with two coil sides per slot, it

can very easily be applied to machines having more than one coil per cell. For instance, if the winding has two coils per cell, this may be indicated as shown in Fig. 4. The diagram is drawn in the same way as it would be for the winding in Fig. 3, but when the end of a series is reached, an indication is made that the winding then continues around the rotor again. This is done in Fig. 4. The ends of all coils at the ends of the series are lettered to show to which coils they must be connected. As the difficulty in connecting is likely to occur only at the ends of each series, the entire series need not be drawn. A few lines, as in Fig. 3, will be sufficient.

This type of drawing shown in Fig. 3 makes it easy to tell where to open the windings and make connections when changing from series to parallel connections, and so on. Suppose, for instance, it is desired to change the winding shown in Fig. 3 from a series to a two-parallel star winding. First taking the *C* phase, all that would be necessary is to open the jumper between slots 82 and 70. Then connect together the top lead of slot No. 1 and the bottom lead of slot No. 70 for the *C* lead. Connect the bottom lead of slot 32 and the top lead of slot 85 to the star point. Likewise for phase *B*, the lead would be connected to the top of slot 33 and the bottom of slot 6, while the star point would be connected to the top of slot 21 and bottom of slot 18.

Wave Windings Where Number of Slots Is Not Multiple of Number of Poles

The other type of wave windings encountered on wound rotors is that in which the number of slots or coils is not a multiple of the number of poles and phases. The number of slots follows the formula for the single series direct-current wave winding. This formula is as follows: $C=(PY\div 2)\pm 1$, in which *C* equals the number of coils, *P* the number of poles and *Y* the coil pitch. If the winding will fit into this formula it may be wound as a single series wave winding.

Fig. 5 is an example of this type of winding. It will be noticed that in this winding the mechanical balance of the leads is not as good as in the type already described. Also one phase has more coils than the others, although in fact this does not do any harm in a rotor. It will be noticed further that three of the slots are neutralized at the instant shown. This means that the current in these slots is passing in opposite directions. These slots are numbers 3, 9 and 20. This winding has twenty-three slots and coils, and is wound for four poles.

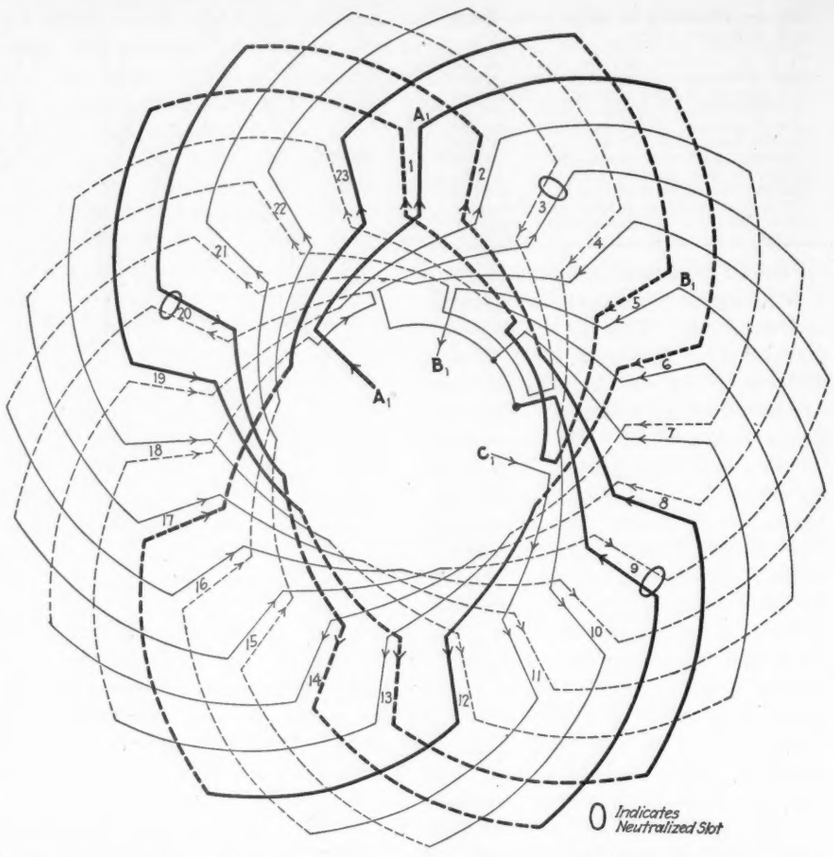


Fig. 5—A rotor winding that is mechanically unbalanced.
There are twenty-three coils in this four-pole wave winding. It is connected for three phases in series-star. The coils are divided into seven, seven and nine per phase, respectively. The winding pitch is 1 and 12, front pitch 1 and 7, and back pitch 1 and 6.

Fig. 6 shows another winding of this type in which the lead arrangement is a little better than that in Fig. 5. This position of the leads depends upon the relative number of slots and coils. There is only one slot in Fig. 6 in which the windings neutralize each other. This is slot No. 15. This is a rotor with nineteen coils and slots and four poles.

This type of winding can be laid out to advantage like the one shown in Fig. 3. First determine the pitch by means of the formula, $Y=(C\pm 1)\div N$, which in the case shown in Fig. 6 is $(19+1)\div 2=10$, which means that the winding pitch is 1 and 11. The back pitch is $10\div 2=5$ or 1 and 6. The front pitch equals the winding pitch minus the back pitch which is $10—5=5$ or a pitch of 1 and 6. The number of coils per section in the six sections equals $19\div 6$ or three coils in each section and a remainder of one coil. This indicates that one section will have one more coil than the others. Altogether there will be five sections with three coils and one section of four coils. If there had been a remainder of two there would be two sections containing one more coil each than the other four sections.

This type of winding is either progressive or retrogressive, depending upon whether the sign $\pm$ in the above formula is plus or minus. If the sign is plus the winding will be progressive, as shown in Fig. 6. If the sign is minus the winding will be retrogressive.

To lay out the winding as shown at the right in Fig. 6, start in slot No. 1 for the *A* lead. Adding the back pitch (5) brings us to the bottom of slot 6. Adding the front pitch of 5 brings us to slot 11. In this manner we pass around through slots 16, 2 and 7. As three coils have been completed, this is the end of the first series. Then add the front pitch (5) to the last slot No. 7, which equals 12. Then the top lead in slot 12 is the *B* lead. Adding pitches we pass in this manner to

slots 17, 3, 8, 13 and 18. This completes the second section. Counting over six slots from slot 18, we come to slot No. 4 which is the slot for the lead of phase *C*. Adding pitches we pass around to slots 4, 9, 14, 19, 5 and 10 to complete the third section. Below these three sections draw a line and start the fourth section. The odd coil mentioned above may as well be put into this section. Starting in the top of slot 10 and adding the front pitch, we reach slot 15 which is the starting point for the fourth section. Adding front and back pitch we place the series in slots 15, 1, 6, 11, 16, 2, 7 and 12, thus including the four coils. For the next section we count ahead five slots to slot 17 and continue in slots 3, 8, 13, 18 and 4. The next section starts in slot 9 and follows through slots 14, 19, 5, 10 and 15. For a straight direct-current, single series wave winding we would connect the bottom of slot 7 to the top of slot 12, the bottom of 18 to the top of 4, the bottom of 10 to the top of 15, etc. However, for the alternating-current winding we must begin with a different connection. We must first find the point to which to connect the leads, reversing jumpers and star connections. The first thing to do is to mark the top three sections *A-B-C*, as shown, and repeat this with the bottom sections. Then the top of slot 1 is the *A* lead. A jumper is put between this section and the other section in the *A* phase which is the fourth section. This jumper is connected from the bottom of slot 7 to the bottom of slot 12. Mark an arrow in the section to show that the coil enters at the *A* lead. It will then pass from right to left in the second section of the *A* phase which is section No. 4. The coils in this fourth section lie in the same slots as the coils in the first section and the current in these slots should be in the same direction for the first section and for the second section. Checking this direction it is seen that the current in slots 1, 11 and 2 passes upward in both sections, while that in slots 6, 16 and 7 passes downward in both sections. This shows that it is proper to connect the jumper to the right-hand end of the fourth section. Then the star lead is in the top of slot 15.

Now the *B* phase is taken as flowing away from the star point, or out on the lead. Therefore, in section 2, the top of slot 12 can be called the star lead, the current going into the slot. Then the top lead in slot 17 of the fifth section can be called the *B* lead. The reversing jumper is connected on to the right hand end of these two sections respectively to the bottom of slot 18 in section 2 and slot 4 in section 5.

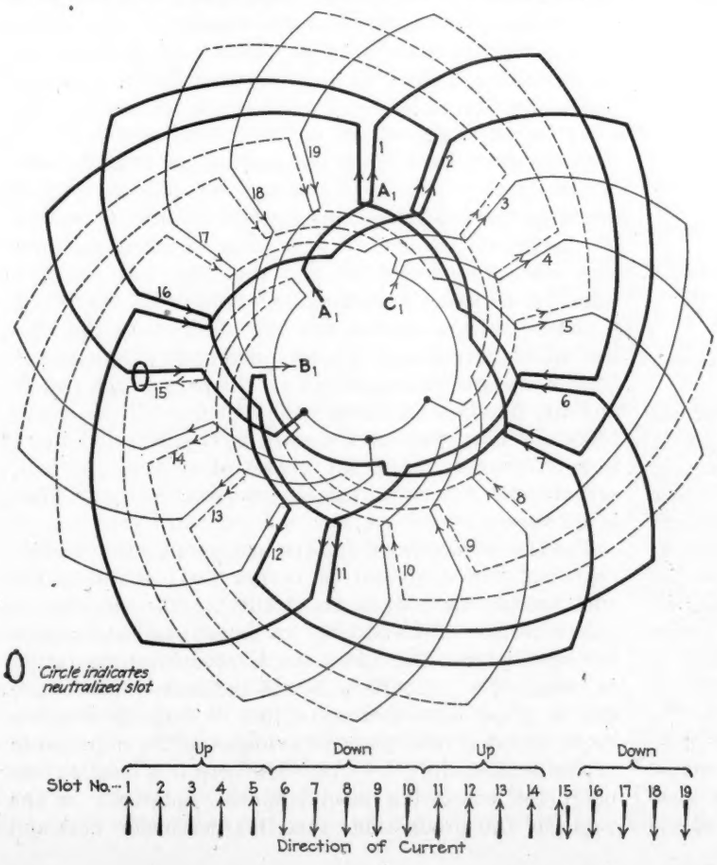
The *C* lead connects to the top of slot 4 (section 3) and the arrow indicates the current is going in. The star lead connects to the top of slot No. 9 in section 6. The reversing jumper is connected from the bottom of slot 10 in section 3 to the bottom of slot 15 in section 6.

If each section is put down in a horizontal line, starting at the left and going to the right, with the six sections under one another as shown in Fig. 6, the connections are easy. The leads for a series-star connection will always be the top of the first left-hand slots in sections 1, 3 and 5. The star leads will always be the tops of the first slots in sec-

(*Continued on page* 555)

Fig. 6—A wave winding for a rotor which is fairly well balanced.

This is a progressive wave winding connected in series-star for three phases and four poles. There are nineteen slots and coils. Winding pitch is 1 and 11; back pitch, 1 and 6, and front pitch, 1 and 6. There are five sections with three coils each and one section with four coils. At the right is the winding laid out in simplified form. The leads connect to the tops of slots 1, 4 and 17. The star points connect to the tops of slots 12, 15 and 19. The reversing jumpers connect together the bottom sides of slots 7 and 12, 18 and 4, 10 and 15.



INDUSTRIAL ENGINEER

Devoted to the Maintenance and Operation of Electrical and Associated Mechanical Systems in Mills and Factories

DANIEL H. BRAYMER
Editorial Director

Assisted by

G. A. VAN BRUNT E. H. HUBERT F. E. GOODING

Chicago, November, 1922

Marks of Good Judgment vs. Extravagance

AMONG the instruction sheets covering operation of electrical installations, issued by a firm of mill engineers doing a large amount of mill work in the South, these significant paragraphs are found:

> The installation should be systematically inspected from time to time by a properly authorized man who should have the responsibility for maintenance. It is suggested that a log book or file of report sheets be kept to establish a record of these inspections.
>
> It is recommended that spare parts be carried for each important piece of apparatus. For large motors and generators, 18 spare coils with slot insulation and wedges and a set of bearings should be carried for each size of machine. For installations comprising a large number of small motors, a spare small motor complete for each size should be carried. Contacts for oil circuit breakers and starting devices should be carried. All spare parts should be properly stocked and tagged so that they can be readily identified. In ordering spare parts, state the nameplate rating and serial number or supply parts number.
>
> Motor fuses should be tested at full amperage before being used. A bad fuse thus discovered may save a motor burnout. This applies particularly to fuses for 10-hp. motors and under.
>
> Master mechanics and electricians from time to time will think of a number of helpful additions to the following instructions. Blank sheets are provided for these suggestions and we ask that copies be sent us for our files so that we can continuously improve these instructions.

These suggestions appear on a general instruction sheet of the report and are aimed at the one thing every man responsible for production abhors; namely, unexpected shutdowns of a department and repair delays, either long or short. In the spinning room and the loom shed of a textile mill where a few large motors drive groups of machines the reason is evident, for the breaking of one thread is closely watched to keep all the looms and all the spindles in operation, but where one motor may stop whole groups of these, the loss in production through a few hours' delay, even two or three times a year, will buy a lot of spare parts. In the case of individual drives the situation is not quite so bad from the standpoint of machines taken out of production, but in this instance spare motors are good insurance and a stock of parts saves telegrams and the wait for the thing that may be inexpensive in itself but all important to the piece of equipment in which it is needed. And all this time production awaits the completion of the repair.

Spare equipment and parts when everything is going beautifully may look like misplaced confidence in sturdy equipment, but no man yet known has been able to predict accurately the extent of repairs from natural wear and tear and the time when accidents will happen. Inspection precautions and reasonable stocks of spare units are, therefore, marks of good judgment rather than extravagance.

Saving at the Spigot and Wasting at the Bung

IN THOSE works where quantity production is essential to adequate return on the capital and labor required in the manufacture of a product, much thinking is devoted to processes and machines that will perform operations quickly and with the least possible supervision by highly skilled hands. In the case where a large machine or group of units are involved a considerable expenditure may be justified on the basis of an increased output or quality of the work done. But in every case it is not always the design or construction of the machine that counts but the reliability of its operation and its ability to automatically do certain work that otherwise would require slower operations and a larger number of skilled operators. Reliability of operation at full production then is the thing that makes it possible to use an expensive outfit at a profit.

In working out the things that stand back of this reliability the same kind of thinking that justifies the use of the machine is often omitted and a production far short of the capability of the mass of metal and its efficiency in operation is the result.

Take, for instance, a large planer, say a 48-in. by 48-in., having a table of not less than 15 ft., with its mechanism driven by two or more separate motors. In order to get the most out of this machine it must be equipped with a system of electric control for the motors so as to enable an average operator to control the table travel and feed quickly and accurately within the limits of the work it will take. Such a machine may cost around $10,000 and the user will see this value in it from a production standpoint, but when it comes to its operation and the selection of the control which constitutes the very nerves of the mechanism, there is a tendency both on the part of the maker and the purchaser to shave the expense of this seemingly auxiliary part of the main mechanism and there is a willingness to accept a control system that will actuate the motors at the lowest possible cost. This is all wrong.

The electrical control and the motor equipment should represent the very best of design and reliability for with inadequate control the ability of the machine to earn a return on the $10,000 investment is handicapped before it is installed and a single production operation is required of it. Here is an instance where there are no great masses of metal and no large floor space requirement to offer physical evidence of the importance of the equipment. Nevertheless, there is a need at this point for exercising good business judgment in the value of full production from this particular unit and

how much this contributes to the end originally in view when the machine was selected; namely, increased plant production and profits through the increased output which can be expected from an efficient machine operated at full production during its operating life, without unexpected failures that can be traced to a five per cent saving on the original investment for electrical control.

Are There Any Signposts in Your Plant?

IF FAILURE and breakdown of equipment can not be entirely prevented, much can be done in various ways to facilitate the work of restoring service and thus shorten the period of shut-down. One way in which time can be saved both in repair and inspection work is to provide a wiring diagram conveniently located for all switchboards, distribution panels, control equipment and so on. In the stress and excitement of emergencies, memory is not altogether reliable and too much reliance on it may lead to the commission of errors for which there is little real excuse. Or, the circuits must be carefully rung out or traced out or a search made for the installation diagrams—in any case, a slow procedure. In the meantime the equipment affected and the workmen who use it are standing idle.

Wiring diagrams located on or close to important pieces of equipment will do away with this confusion and waste of time. Little expense need be entailed in making these diagrams. The chief requirement is that they be accurate and show the wiring scheme clearly. If blueprints are not available a sketch in ink on white paper will serve equally well.

In the same way time and trouble can be saved by clearly distinguishing steam, water, gas and other pipe lines around the plant so that a glance will show what they are. Painting each line a different color is a simple and effective mode of identification. Inasmuch as pipe lines are in many cases painted anyway for the sake of appearance, there is little or no extra expense incurred in making the paint serve a useful as well as an ornamental purpose.

Signposts cost little compared to the time and labor which they save.

Ways to Multiply Skill at a Profit

AROUND shops a saying is current to the effect that "It takes good tools for a poor workman to do a good job, but a good workman can do a good job with any kind of tools." When an inventory of tools is made on this basis in the average motor repair shop, the only inference that can be drawn is that the workmen must be extra good. But when the work is closely examined the need for good tools is easily apparent. In armature winding involving the making of coils, the preparing of insulation, and the placing and connecting of coils in the machines, the item of labor is all-important in the total cost of the job. Any device, therefore, which will enable a skilled winder to save time on a job is not only a good investment, but insurance against the many troubles that result from pounding and forcing poorly made coils and the waste of time in locating these troubles and correcting them.

A good coil winding device and a spreader that will produce coils of the correct shape and dimensions may cost a considerable sum, but they are cheap at almost any price. Then there are insulation cutters, taping machines, insulation strippers and trouble testers and instruments that not only save time but a lot of material in the course of a year. In one well-equipped shop it used to take better than six hours to place the coils in a 5-hp. induction motor stator. The same job is now being done in less than half that time by the same winders simply because the coils are accurately formed and the insulation applied by machines so that the coils fit the slots easily. More than half the troubles experienced have been eliminated and besides the job looks better when finished. After all, a good-looking job that stands up, at a reasonable price, is a better advertisement for any shop than just a fair-looking job, which cannot be guaranteed from a service standpoint, at a much lower price.

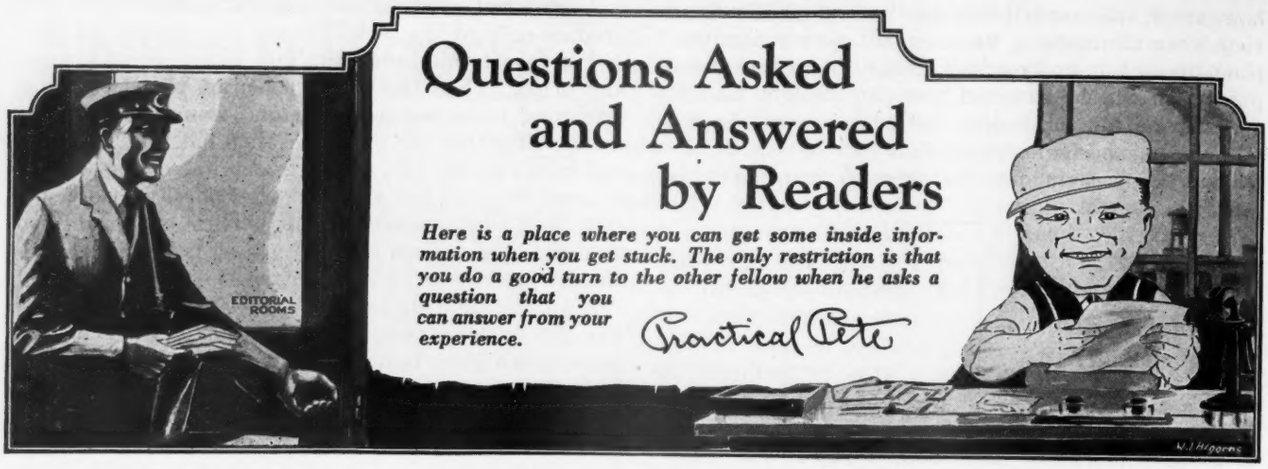
Armature winding is as old a process as the use of motors themselves, but we have learned a lot about insulation and coil making in the past ten years. And in nearly every repair shop there is a genius in the winding art and the skill required to diagnose troubles and correct them. Such a man can earn a nice profit on his ability if he will equip his shop so that he can train younger men in the work and apply his experience and skill through more heads and hands with results equal to those he himself can show.

Are Shop Instructions Up to Date?

WHILE a shop or department of an industrial works cannot be run by a code of rules alone, still all good organizations have an established procedure, which is nothing more nor less than a set of operating rules, even though they may not be written. A shop can no more get along without rules than can a nation without laws. In either case, however, the mere fact that the rules or laws exist does not mean anything; it's the living up to them and their enforcement that counts. But wherever progress is evident, laws or rules of any kind are constantly changing, since this is the only way that changing conditions can be successfully met. This is especially true in maintenance work of industrial plants, particularly in that part related to the operation and care of electrical equipment.

Someone said at one time that "Rules are like a suit of clothes. They fit when they are applied but need to be constantly brushed and pressed to keep them fit." If the rules governing your department are a number of years old, see how many of them are really dead letters and have been supplanted by more recent ones even though their incorporation has not been acknowledged. Perhaps a number of them are completely out of date. This applies to any type of printed instructions or specifications as well as to shop rules covering the activities of the workers.

Perhaps it would be well to "brush them up a bit." In the case of fixed rules which are established by organizations outside of your own control, such as the National Board of Fire Underwriters or local codes, it may be well to "brush up" on them. They change from time to time, too.


EDITORIAL ROOMS
Questions Asked and Answered by Readers
Here is a place where you can get some inside information when you get stuck. The only restriction is that you do a good turn to the other fellow when he asks a question that you can answer from your experience.
Practical Pete

Who Can Answer These?

Heat Resisting and Insulating Cement.—I have been referred to the INDUSTRIAL ENGINEER by the A & M College of Texas for a good type of heat resisting and insulating cement and also a kind of insulation that will take the place of porcelain. We desire an insulating material that can be shaped, drilled when necessary and will stand heat if exposed to fire. Any information you can furnish will be appreciated.
Bartlett, Tex. A. C. H.

* * * *

Small Condenser for 110-Volt A. C. Circuit—I want to make some experiments with condensers on a. c. circuits of 110 volts, the capacity of the condensers to be approximately one microfarad. 1. Where can I obtain the necessary sheets of tin foil? 2. What should I use for the dielectric? 3. Where can I obtain same? 4. What thickness should the dielectric be for 110 volts a. c.? I have never seen any of this material advertised, consequently this request to you.
Logansport, Ind. L. E. G.

* * * *

Wiring Diagram for Single-Phase Motor Winding—I would appreciate the publication in Industrial Engineer of a wiring diagram for a single-phase, constant-speed, continuous-duty motor. The motor in question is a Westinghouse design, bearing the following nameplate data: 4-amp., 110-volt, 60-cycle, 1,700 r.p.m., style SO 366518, Serial No. 830837. The stator has 24 slots and a centrifugal switch on the rotor. Please also give the size of wire for both the starting and running windings and the number of turns per slot.
Blackstone, Mass. W. J. R.

* * * *

Connections for Ampere-Hour Meter.—I have an ampere-hour meter marked Woods Electric and am unable to find out how it is to be placed in either a charging or discharging circuit. There are three leads coming off the meter. Two of the leads are double. In one of them one wire has a red and the other a blue-colored insulation. The other double lead contains one yellow and one green insulated wire. The third lead is a single black wire. I should like to know if there is someone who has had experience with this instrument or can give me a diagram as to how it should be connected.
Cleveland, Ohio. R. E. P.

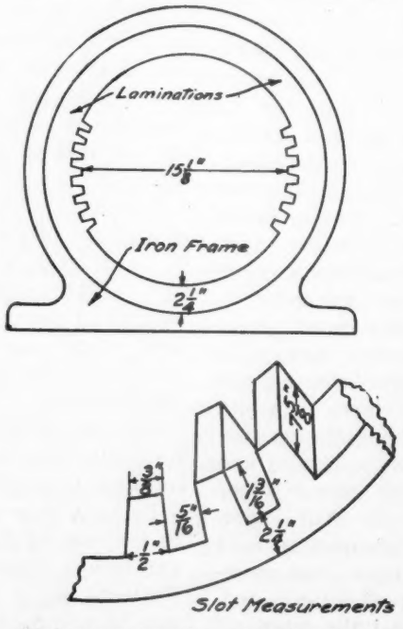
* * * *

Removing Coils From Motors Without Damaging.—Is it possible to strip an armature or stator of coils and save these coils for rewinding.
Brooklyn, N. Y. I. T.

* * * *

Figuring Horsepower of Motor from Winding Data—I have a motor with the nameplate taken off so that the rating is not known. Will someone please tell how to figure the horsepower and the ampere rating from the sketch and data which follows?

This motor has been operating on a 440-volt, 3-phase, 60-cycle circuit. The old winding had coils of 7 turns of No. 16 B & S gage wire, 3 wires in parallel. There are 72 slots with 18 pole phase groups or 6 poles per phase, with a total of 72 coils. The coil pitch is 1 to 11 and the connection is a one-circuit star. The rotor of this motor is bar-wound and not of the slip-ring type.
Wisconsin Rapids, Wis. I. D. K.



Stator construction of motor to be rewound.

Answers Received To Questions Asked

Use of Wire Tables.—In the June number I was interested in the wire tables that were a part of the article on diagrams for winding coils by Mr. Roe, but I do not understand the method of figuring the circular mils from square mils in handling the square wire and ribbon wire. From the formulae I have used the values obtained are greater than those in the tables. I wish someone would explain how to use such formulae in conjunction with the data and tables.
Norwood, Mass. R. E. L.

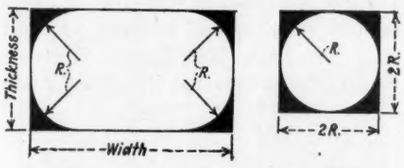
In any case the number of circular mils equals the number of square inches multiplied by 1,273,236. On all square wire and ribbon or strap copper, the corners are rounded. So when calculating the area of a square or ribbon wire, allowance must be made for the rounding of the corners. The table on page 543 gives the radius of the corners for square and ribbon wire used by one manufacturer. Other makes differ little.

As an example, take a wire 0.3000 in. x 0.4000 in. in size. This has an apparent area of 0.300×0.400 or 0.12000 sq. in. The table (Table IV page 287, June INDUSTRIAL ENGINEER) gives 0.11664 sq. in. The difference is in the amount taken off by rounding the corners. Referring to the accompanying drawing we see how this amount may be calculated. The pieces taken off the four corners of the cross section shown at the left will fit together to form the square shown at the right. The side of the square equals $2R$. The black portion equals the area of the square minus the area of the circle or $4R^2 - 3.1416R^2 = 0.8584R^2$. But in the present case R is seen from the accompanying table to be 0.063 in. Therefore the amount lost in rounding the corners is $0.8584 \times 0.063^2 = 0.00341$ sq. in. The area then is (0.12000—

Cross-Sectional Area and Radius of Corners of Ribbon and Square Wire

Cross-sectional area in square inches equals: [Thickness (inches) × width (inches)]—K, where K equals value shown in right-hand column. This value equals $0.8584R^2$.

Thickness of Ribbon, Inches	Radius, R, Inches	Value of K
0.050 or less	Half the thickness	$0.8584R^2$
0.051 to 0.105	0.025	0.000536
0.106 to 0.165	0.031	0.000824
0.166 to 0.225	0.047	0.00189
0.226 to 0.438	0.063	0.00341



The corners of rectangular conductors ordinarily used in motor windings are rounded with a radius in the figure to the left. The values of this radius for different sizes of wire are given in the accompanying table. The area of the conductor equals the width multiplied by the thickness minus the black corners shown in the figure. The area of the black corners is calculated as shown in the figure at the right and equals ($4R^2$—$3.1416R^2$) or $0.8584R^2$.

0.00341)=0.11669 sq. in., practically the same as that shown in Table IV. The circular mils equal 0.11669× 1,273,236 or 148,536. As the tables were prepared from data of several manufacturers the values given may differ slightly from those calculated according to the accompanying plan, but the difference is small.

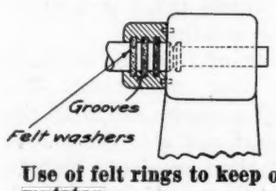
Detroit, Mich. A. C. Roe.

* * * *

Oil on Generator Commutator.—We are having trouble with oil working onto the commutator of a 16-kw. d.c. generator. The bearing is run with the oil as low as possible, but still a little gets past. I would appreciate details of a method to stop this.

Alta, Canada. W. S.

In regard to the trouble which W. S. mentioned recently in INDUSTRIAL ENGINEER, referring to oil getting onto a commutator, I would suggest



Use of felt rings to keep oil off commutator.

that he make an addition to the bearing in the form of a brass casting, as shown by the accompanying illustration. This casting should be grooved on the inside so that two or three felt washers at least ¼ in. thick could be put on the shaft and held in place by this casting. Its shape and method of attaching will depend upon the construction of the motor bearing.

Detroit, Mich. A. C. Roe.

Methods for Changing Frequency—Please explain how the frequency of a supply circuit from an a. c. generator can be changed to a higher or lower value. Can this be done by stationary apparatus; that is, without moving parts, and if so, please explain the method and equipment used?

Brooklyn, N. Y. A. D.

Frequency changing is accomplished by means of a frequency changer set, which is a generator designed for the frequency desired, driven by a motor designed for the frequency of the supply circuit. These are usually direct-connected and constitute a motor-generator set.

Ansonia, Conn. W. T. Estlick.

* * * *

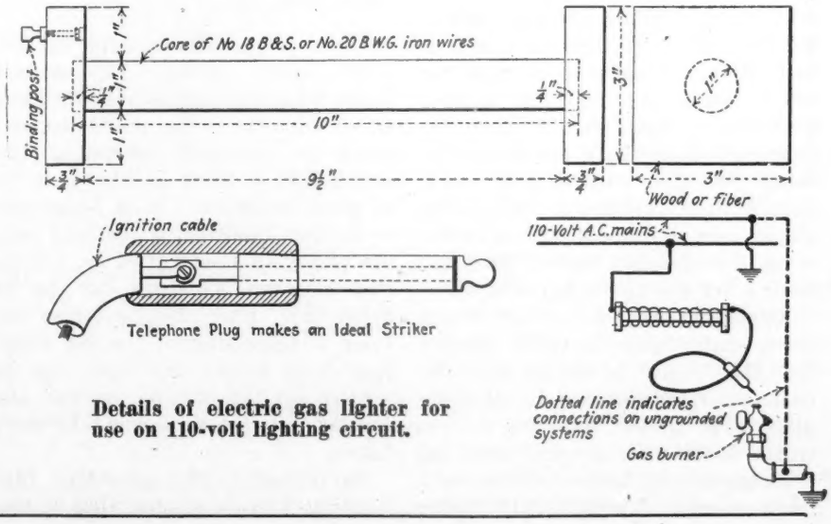
Lighting Gas by Electricity.—I would appreciate details of a method by which a 60-cycle, 110-volt, alternating current circuit can be used to light a gas jet instead of using matches. A sketch of a device for this purpose would be helpful.

Wilmington, Del. J. H. G.

In answer to J. H. G. in the August issue I am inclosing specifications and wiring diagram for an electric gas lighter for operation on 110-volt, 60-cycle, a.c. house-lighting circuit, which I have wound and installed on our gas range and has given very satisfactory results.

The core is made up of iron wires 10 in. long formed into a cylinder 1 in. in diameter. For this purpose use about No. 18 B. & S. gage or the No. 20 B. W. gage. The cylinder should be insulated by rolling around it about four turns of thin fiber. On each end of the core are placed wooden blocks as shown. The winding consists of six layers or about 800 turns of No. 16 B. & S. double-cotton-covered magnet wire. This is brought out to two binding posts one of which is connected to the line by means of insulated wire and the other is connected to the striker. For a striker a piece of heavy copper wire insulated by a fiber or tape sleeve may be employed. An old telephone plug makes an ideal striker. A length of ignition cable should be connected from the coil to the striker. This should be connected only to the center contact of the telephone plug if such a plug is used. The striker is touched to the burner and on withdrawal produces a spark which will light the gas.

In wiring for this type of circuit it is necessary to have one side of the line connected to the frame of the stove and in this case the characteristics of the system to which you are connected must be taken into consideration. To illustrate: Most city lighting systems are operated with a grounded neutral, for three-wire distribution, and it can be readily seen that in this case the gas distributing system is in reality already one side of the line. Therefore, if one of the line wires is connected to the stove for the return and this happens to be the outside leg of the circuit, a short circuit is the result and the fuses will be blown. If there is no information available as to the distribution system, it will be necessary to try out one side of the line at a time through the coil or a test lamp to see if a spark or light is obtained when the striker is touched to the stove or gas jet. If the connection from the coil to the lighting circuit is made through an attachment plug, it should be of the non-reversible type (in the case of a grounded distribution system) so that if it is disconnected at any time for any reason, it will connect up the proper leg of the circuit to the coil when it is



Details of electric gas lighter for use on 110-volt lighting circuit.

plugged in again. It might be well to remark in passing, that a good "kick" can be had from this lighter if a person touches the end of the striker and the stove or any metal touching the stove at the same time, and it should therefore be treated as a hazardous apparatus.

G. E. SWARTZ.
Instructor, Healds Engineering School, San Francisco, Cal.

* * * *

Tool Box for Electrician's Equipment.—Several designs of tool boxes are made suitable for tools used by a machinist. I would like to ask fellow electricians to offer for publication in INDUSTRIAL ENGINEER the construction and design for any special tool box which they have found convenient for carrying around the shop the tools that are commonly used and purchased by them personally. I have in mind a small size tool case about 2½ ft. long by 24 in. wide by 24 in. deep with suitable trays and compartments.

Chicago, Ill. J. M. B.

In the August issue J. M. B. requested a design of tool box suitable for housing personal tools of electricians. We have found the Vanderman sheet metal tool box satisfactory for this purpose and recommend it to our construction crews. The type we use is about 16 by 17 by 36 in. with one tray. The tray is of wood construction and the lower part of metal construction. This type of tool box is made by the Vanderman Manufacturing Company, Willimantic, Conn.

Greenville, S. C. R. L. V.

* * * *

Testing Motor Field Coils—Is it good practice to apply voltage across the shunt fields of a motor for several hours to test for heating? I am having trouble with the blowing of the main fuse on my generator, although the machine is not overloaded. Can you tell what causes this trouble?

New Orleans, La. A. C. H.

In the September issue A. C. H. asks a question on the testing of motor field coils. If the coils are connected to pull normal voltage for about thirty minutes, any serious tendency to heat should show up. However, there isn't anything like being absolutely sure of your work, and a test of from two to three hours might reveal defects which would cause considerable loss of time and labor after the motor is installed.

Regarding the generator which blows main fuses, I would suggest that the trouble is due to instantaneous overloads caused by starting up a large motor, or other devices on the distribution system, requiring a comparatively large current for a few moments. A good circuit breaker of the time-limit type in place of the fuses ought to remedy your trouble. It would, also, save the cost of frequent fuse renewals.

Chicago, Ill. D. F. O'DONNELL.

* * * *

When necessary to test the shunt field circuit in this way for heating without running the motor, no harm can be done by applying the rated d.c. voltage to the circuit with all the resistance turned in, providing the amount of current is under control by a rheostat and observation by a meter with shunt, and sufficient time is allowed for the coil and core to heat uniformly before increasing the current. The effects of armature reaction while the motor is running is a small percentage of the magnetization and its absence would not be harmful. Do not allow the field coil temperature to rise higher than 90 deg. C. measured by a thermometer applied to the hottest part of the surface.

Concerning the generator fuses, if the rating of the fuse is greater than the peak load on the generator, the cause of the trouble may be about the fuse itself. Clips may make a poor fit or some poor connection may cause local heating and blow the fuse. Polish fuse blades and contact surfaces of clips, replace fuse and examine condition of contact by trying to insert a 0.0015-in. feeler between them. As a last resort of temporary nature to make good contact, apply small clamps with broad flat plates under them to force ample contact. Clean and check the contact between the conductor lugs or connections to fuse block. When refilling fuses provide clean smooth contact surfaces and provide brass washers to insure ample contact.

Smooth Rock Falls, Ont., Can. W. A. PLANT.

* * * *

There is no harm in applying the rated motor voltage for several hours for a heat test on a shunt field, either with the armature in the machine or removed, providing the shunt field winding is known to be in good condition. It is dangerous to do this, however, if the field coils are partly short-circuited as, for instance, when moisture has to be dried out. Excessive heat may develop in the center of the coil windings long before any heat can be noticed on the outside, so that the insulation may be burned between turns.

In regard to the generator fuse blowing, I would suggest that an ammeter reading of the circuit in question be taken to make sure that the current value does not at times exceed the fuse rating. If it does not, carefully examine the fuse clips and cable connections; also the contact made by the switch, if there is one in the circuit. See if any of these contacts and connections get hot. Very often fuses are melted or overheated from a bad contact so that they will blow long before the current actually reaches the rated value of the fuse.

Omaha, Neb. W. E. PAULSEN.

* * * *

A. C. H. asks if it is good practice to apply voltage across shunts to test for heating. This is a good way as long as the voltage is proper and the fields are correctly fused. Never shunt the fields without fusing them properly. If his fuses are not overloaded he might possibly have a loose or dirty connection either between his fuses and service or very close to the fuses; as for example at the lugs.

If his fuses blow immediately after the switch is thrown in, a short circuit beyond the switch is possibly the trouble. If all his connections are tight and the fuses blow some time after the switch is thrown in, it might be advisable to put in heavier fuses.

Peoria, Ill. GEO. RINGNESS.

* * * *

As the current in the shunt field is fairly constant providing the voltage of the machine is constant, undue heating should show up in a reasonable amount of time, depending on the characteristic of the trouble. But as the shunt field is designed for practically line voltage the writer sees no danger in making such a test unless there is a short circuit in the winding.

The blowing of the fuse is probably due to poor connection. The writer would suggest cleaning the fuse clips good and also the cutout clips and if they are loose tighten up a bit on them. Make sure always that you have a good clean connection when replacing fuses, as heating at this point lowers the capacity of the fuses.

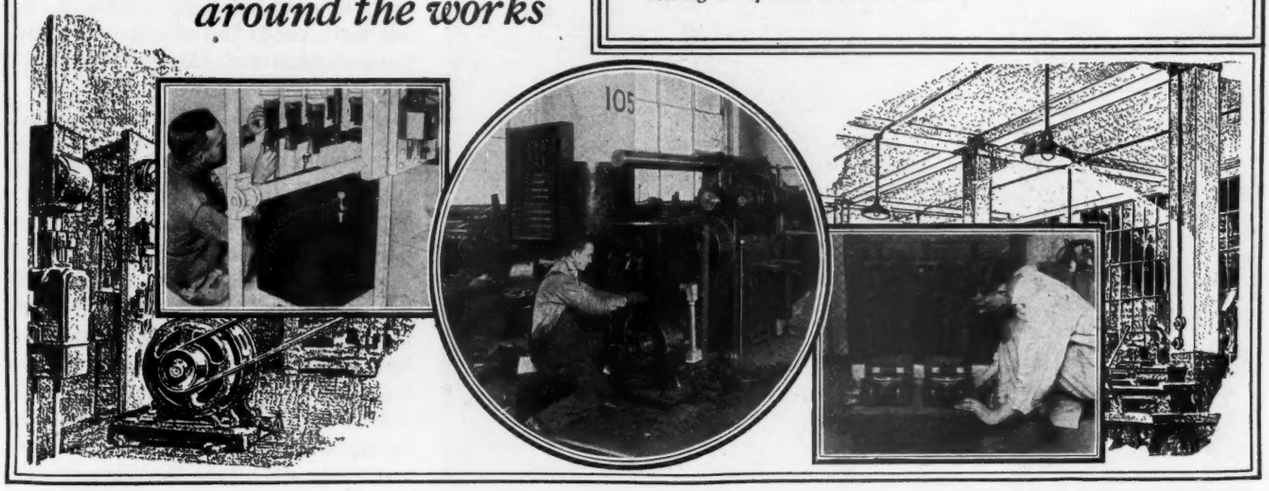
Ansonia, Conn. WILLIAM T. ESTLICK.

* * * *

These several answers to his A. C. H.'s question are published in order that he can check up the suggestions and give the results for further analysis in case the remedies outlined do not locate the trouble.—EDITORS.

SERVICE
around the works

For this section ideas and practical methods devised to meet particular operating conditions are invited from readers. The items may refer to inspection, overhauling, testing or special installations.

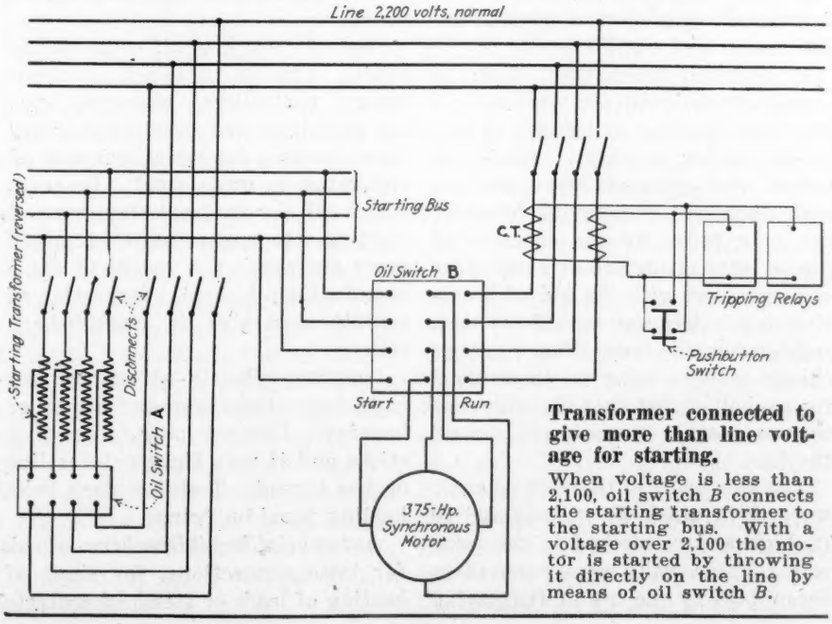


Connection for Starting Motor When Line Voltage Is Often Low

AN ARRANGEMENT for starting a motor on an alternating-current line whose voltage was sometimes quite low was recently installed in a New Jersey factory. By means of special connections the motor can now be satisfactorily started whether line voltage is normal or excessively low.

The motor is a 375-hp., 2200-volt, two-phase synchronous machine with a squirrel-cage starting winding. It drives an ammonia compressor in an ice plant and was designed to start under 30 per cent load. An auto-transformer was connected in to furnish the starting voltage. The highest tap on the auto-transformer, approximately 1800 volts, gave the most satisfactory operation.

Lately, however, we were confronted with considerable starting trouble, because the line voltage was sometimes as low as 1900 volts. Moreover, the owner of the plant wanted the motor to start under a higher load than 30 per cent, to avoid the necessity of cleaning out the cylinders of the compressor after an accidental shut-down. To meet the last demand, 2200 volts are necessary for starting. The motor can stand this because its impedance is so high that at 2200 volts it draws only 170 amp. when not rotating (normal load is 73 amp.).



Transformer connected to give more than line voltage for starting.

When voltage is less than 2,100, oil switch *B* connects the starting transformer to the starting bus. With a voltage over 2,100 the motor is started by throwing it directly on the line by means of oil switch *B*.

To be able to start with a line voltage of 1,900 we had to step the voltage up. We connected the "tap" of the starting transformer to the line and the "line" end to the motor side. In this way we obtained the 2,200 volts necessary for starting, when the line voltage was 1,800.

The connections were made as shown in the accompanying sketch. The operation now is as follows: When line voltage is 2,100 or over, start the motor by throwing switch *B* to the running position. When line voltage is under 2,100, connect the auto-transformer to the starting bus by means of oil switch *A* and throw oil switch *B* to the starting side. When the motor is in synchronism throw switch *B* to the running side.

The motor is protected against over-current by a direct-trip attachment with two Westinghouse type CO relays (adjustable definite-minimum overload relay with inverse time-limit). These relays have the standard time scale up to ten seconds. But it takes the motor much longer than ten seconds to pull in step. So at first we set the relays so high that they would not trip the running switch when the starting current was flowing. This, however, gave no adequate protection under running conditions. On overload the motor would drop out of step and draw current equal to full starting current until it would burn up.

To overcome this difficulty we set the relays to trip at a slight overload and installed a two-pole pushbutton switch to short circuit the relays

Do you ever have to demolish a reinforced concrete wall or foundation?

Instead of laboriously smashing this wall with hand sledges, Ingersoll-Rand paving breakers, operated by compressed air, broke it up much quicker and at less expense. The paving breaker operates as a compressed air pick and chiseling machine similar to a non-rotating hand-hammer rock drill. One man operated it when working down on the ceiling. When working on the inside of the concrete vault a part of the weight was carried on chains supported by reinforcing bars in tne ceiling.

and trip coils during the starting period. The button is held in by the operator while starting. The spring in this switch opens the short circuit immediately when the operator takes his hand off the button after the motor has pulled in to step. This eliminates the "human element" of forgetting to put the protection on after starting the motor.

Brooklyn, N. Y. JAN A. VANDERPOLL.

Compressed-Air Driven Paving Breakers Used to Remove Concrete Wall

RECENTLY it was found necessary to remove the side walls and top of a large venturi plant and a section of the west wall of the filter building of the Cleveland, Ohio, filtration plant. The accompanying illustration shows how a section of the concrete wall was removed. The wall of the filter building was 23 ft. in length, 20 ft. in depth and 24 in. thick and reinforced with ½ to ¾-in. rod, spaced on 8-in. centers. This made a very solid formation which was difficult to remove.

Originally the plans were to do this work by hand. However, the Lake Erie Construction Company, to which this contract was assigned, tried out an Ingersoll-Rand CC-25 "paving breaker" which is an automatic, compressed-air-operated pick and chiseling machine. It is similar to a non-rotating hand-hammer rock drill, is light, extremely simple and operated by one man when working downward. In this particular case, however, it was found advantageous to use two men to each machine. Until recently paving breakers have been principally used by street railway, telephone, electric, power and gas companies for tearing up pavement of all kinds, for the laying and repairing of street railway tracks and the laying of electric cable ducts, gas mains, and similar work.

It required three days' time to completely demolish the west wall of the filter building by the use of two CC-25 paving breakers. As stated before, two operators were used on each machine. The paving breakers not only broke up the concrete in pieces large enough to be handled by one man, but with the aid of a cutting chisel they also cut off the steel reinforcing side rods. These cutting chisels were similar to those used for asphalt except that the edge was concave so that it would not slip off the bar.

The side walls of the venturi vault were 12 in. thick, 51 ft. long and 10 ft. high and reinforced in the same way. These walls were removed in seven days by the use of the paving breakers. The roof of the venturi vault which was of the same dimensions and construction as the side was removed in 3½ days. This work would have taken many more men a much longer time to do if hand methods were used, and would have been more expensive. M. A. O'BRIEN.

Lake Erie Construction Co., Cleveland, Ohio.

Inspection System Which Keeps 1,200 Motors Running

TO "KEEP the wheels turning" the maintenance system developed in a Canadian textile mill has been found successful with 1,200 motors ranging from ¼ hp. to 250 hp. in size. Inspections are made as follows:

Motors.—Very little inspection can be made of motors when in position, but in the open type the air gap may be noted. See if oil is creeping along the shaft and being thrown on the stator coils, or if there is any vibration. Oilers must notify the electrical department when a motor is hotter than usual. Motors are thoroughly overhauled once a year, for which purpose they are carried to the shop, taken apart, cleaned, the bearings attended to and the motors revarnished and tested. If a spare machine is not available, the overhauling is done at the week end. In very dirty places it is advisable to drain the oil from bearings every six months. If the oil is clear after it has settled some time, it can be used again. In textile mills look out for cotton fluff forming a siphon. See that the oil rings revolve freely; to test, try turning them with a lead pencil.

Control Equipment. — Isolating panels, circuit breakers, compensators, controllers, resistors, etc., are examined and overhauled every three months, for which purpose all apparatus is made dead. In cases which call for frequent stopping and starting, the apparatus is examined every six weeks. A record of these examinations is kept. Inspection of control apparatus is classified as follows:

Isolating Panels.—Examine for loose connections, signs of arcing or burning. Unscrew plug to see if it sticks and if very tight put vaseline on the thread. Test for slack bolts holding panel on frame.

Automatic Circuit Breakers.—Look for loose connections, for signs of heating of leads or stems of contacts

and for bad contacts. If contacts are burned, renew them. Examine oil for sediment and height. Examine time element for loose nuts, screws, etc. Remove dashpot, examine needle valve, see if oil is clean and at right level, replace dashpot, close breaker and test operation.

Overload Relays.—Same as for circuit breakers. Examine silver contacts of toggle switch which operates the no-voltage coil. Test.

Fuse Boxes.—Look for loose connections, signs of heating by color of contacts; test amount of spring in the fuse clips; also look for loose bolts.

Compensators.—Remove case and examine for loose connections, condition of insulation, etc. Examine contacts; file and adjust, and renew bad ones. See that the handle works freely and the pawl engages correctly. If any sediment is in oil tank, throw away old oil, clean out tank and fill with new oil. Examine plunger of no-voltage coil.

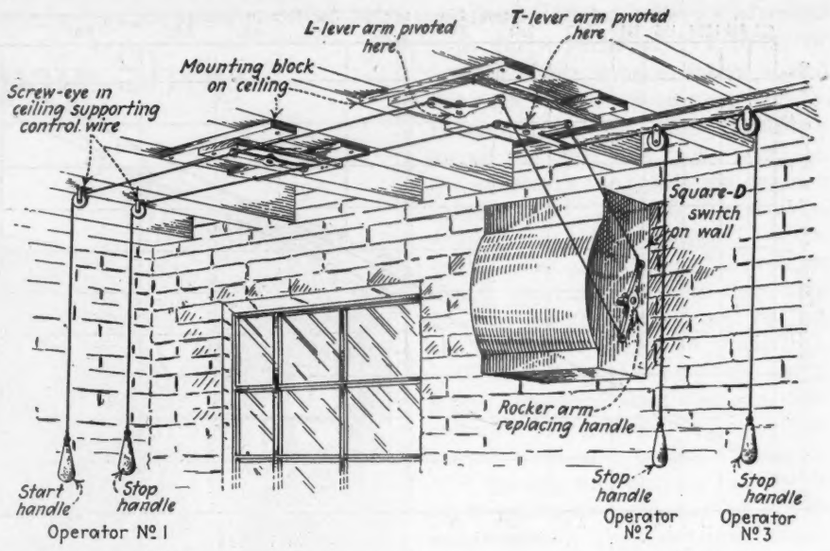
Ground Wires.—Examine the connections on the water pipe or other ground for signs of rust or corrosion. Examine whole length of ground wire.

H. E. WOOD.

Glasgow, Scotland.

Putting Stop Control Within Reach of Three Men on Automatic Machine

MANY times when a machine has several operators provision must be made so that any operator can stop it instantly. Such was the case in the operation of an automatic can-filling machine in one food products plant. Here something might go wrong at any time, and to prevent waste and loss, drop cords with pear-shaped handles were dropped to each of the three operators' positions from the stop side of the arrangement shown in the accompanying sketch. A Square-D switch with a straight rocker arm instead of a lever control was placed on the adjoining wall about two feet from the ceiling. Steel wires were connected from the starting and stop arms to two 90-deg. arms which were fastened to a wooden block on the ceiling directly above the machine, as shown. The wire to the stop arm is extended on out through screw-eyes in the ceiling over the machine and the drop cords extend down to a convenient height so that one is within reach of each of the three operators.



This arrangement permits any one of three operators to stop the machine, but only the first operator can start it from his working position.

The start lever arm is connected so that only the first operator can start up. For this a tight wire is stretched from the 90-deg. rocker arm to a straight arm, as shown, before attaching to the first operator's cord. With the two cords and the straight arm the operator can manipulate the switch as necessary. As a very oily product is handled, it was considered better to put the control apparatus overhead than to use push-button control, which would have required conduit and wiring on the equipment, with added surface and corners to be kept clean.

F. E. G.

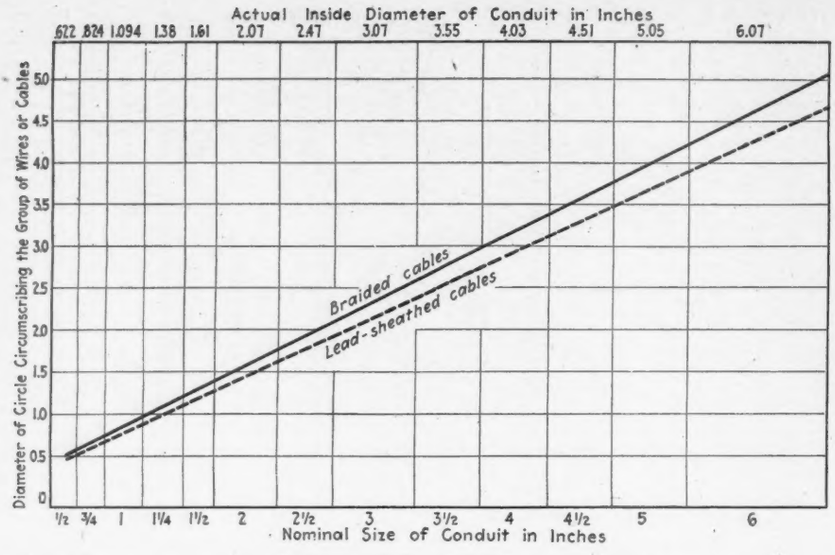
Chicago, Ill.

Care and Operation of Commutators on New Machines

COMMUTATORS on new machines require special attention to insure best operation and to lessen future troubles. During the first few months that a machine is run under load the commutator is "seasoning." That is, the mica is settling into permanent position and the binding material (usually shellac) is working out from points which are under pressure. During this period the commutator bolts should be tried every two or three weeks while the machine is warm, and if found slack they should be set up tight. In setting up the bolts a little slack should be taken on each one all the way around, then a little more, and so on until all are tight. Where the flange is in short pieces the middle bolt in each piece should be set up first, then the end bolts and then any others in between, giving uniform pressure on the whole flange section. It is possible to set the bolts too tight; hence an extra large wrench should not be used. After the seasoning period the commutator may be out of "true," and if so it should be turned or ground.

A good commutator has a dark-brown color and high polish. When first put in service the copper is raw and pink, but it can be burnished with a hard piece of canvas fastened on a wood block and moistened with a little engine oil. Some grades of brush, particularly soft graphite or "doped" or paraffined brushes, smut the commutator with black dirt and prevent the formation of a good polish; in such a case the smut should be washed off with a rag dampened with gasoline while the machine is shut down. Do not use too much gasoline as it is liable to dissolve grease and dirt and carry them into the mica, where carbonization may take place, causing short-circuits in collars or between bars. Kerosene should never be used for cleaning commutators, because it lodges in the mica, never getting dry, and thus frequently causes short-circuits to start.

To take down high mica or remove small flat spots or ridges use a sandstone, a carborundum block or a piece of grindstone. The stone should be anchored so that the man can give his attention to putting on pressure with no danger of the stone being pulled out of his hands. Often a strap-iron stirrup can be bolted on the brush arm to guide the stone. To avoid glazing the stone, all dirt should first be re-


Actual Inside Diameter of Conduit in Inches
.622 .824 1.094 1.38 1.61 2.07 2.47 3.07 3.55 4.03 4.51 5.05 6.07
Diameter of Circle Circumscribing the Group of Wires or Cables
0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0
Braided cables
Lead-sheathed cables
½ ¾ 1 1¼ 1½ 2 2½ 3 3½ 4 4½ 5 6
Nominal Size of Conduit in Inches

Conduit sizes for braided wires and lead-sheathed cables.

These curves may be used for any kind of wires, as they are based on the outside diameter of a single wire. When more than one wire is to be enclosed in the same conduit, the conduit size depends on the diameter of the circle which will circumscribe all of the wires. The diameter of this circumscribing circle may be obtained from the table below if the diameter of one of the wires is known. To determine it, the diameter of one wire is multiplied by the constant "*K*" shown in the right-hand column of the table, this constant being taken to correspond to the number of wires in the particular case as given in the left-hand column. Let *D* equal diameter of circumscribing circle; *d* equal over-all diameter of individual wire or cable and *K* equal constant given in the table. Then *D* equals *dK*.

TABLE OF CONSTANTS

No. of Wires or Cables	Values of "*K*"	No. of Wires or Cables	Values of "*K*"
1	1.	25	6.657
2	2.	37	7.
3	2.155	61	9.
4	2.414	91	11.
7	3.	127	13.
9	3.828	169	15.
13	4.732	217	17.
19	5.		

moved by a damp gasoline-rag and vigorous sandpapering until the copper shows pink. Then the stone will be able to cut steadily. After stoning polish with fine sandpaper moistened with a little oil and burnish with a hard, oily rag backed up with a block of wood. During stoning all the brushes should be removed or raised. Careless handling of a commutator stone on a rapidly running machine is dangerous both to the machine and the workman, who must use care to avoid damage.

Never use waste for wiping off a commutator. The lint will stick to the copper and be carried under the brushes and cause sparking or glowing. Cheesecloth, a piece of clean cement bag or a scrap of overall cloth is much better.

When sufficient lubrication is not given automatically by the brushes it is sometimes advisable to put on a little good engine oil to stop brushes from squealing. The oil should be put on a canvas pad, which is passed over the surface of the commutator. Immediately afterward a clean rag should be used to wipe off the excess oil. Under ordinary conditions no lubrication is necessary. Regular wiping with a dry rag will keep the surface good.

Most commutator breakdowns are caused by oil getting into the mica and carbonizing. Oil may accumulate from bearings either in fluid form or by throwing or creepage along the shaft or by deposit of atomized oil from warm bearings. There are other sources of oil, such as overhead cranes, that must be watched for. The oil soaks in the mica and collects dirt. After a while the warmth and drying carbonize the oil and the insulating qualities of the mica disappear, allowing breakdown from bar to bar or between bars and ground.

JAMES DIXON.

St. Louis, Mo.

How to Determine Size of Conduit Required for Wires and Cables

NUMEROUS tables have been published giving the size of conduit required for certain sizes and numbers of wires and cables, but practically all of these appear to provide only for 600-volt rubber-covered "Code" wires. They do not cover the problem as applied to lead-sheathed cables, cables of higher voltages than 600 and wires for telephone and signaling systems.

Installations requiring the use of conductors other than those covered in the 600-volt "Code" class are being made in great numbers and the practice as to conduit sizes is not by any means uniform, because there has not been a definite rule whereby predetermination could be made.

From the results of actual experience over a period of eight years in connection with the determination of conduit sizes for the various combinations of conductors two curves covering, respectively, braided and lead-sheathed cables have been devised and are given in the illustration. It was at first believed that the size of conduit for wires having the same diameter would be the same whether the outer covering were braid or lead. It has, however, been found that due to the gripping resistance of the lead and the possibility of resulting damage to it, a slight difference should be allowed.

After working out the curves, comparisons were made with their requirements and those of the "Code" and of other published tables as applied to 600-volt rubber-covered wires. It was found that, with few exceptions, they agree. It will be noted that the abscissa divisions are proportioned to the difference in internal diameter of the conduit, and it is due to this spacing that the curves resolve themselves into a straight line.

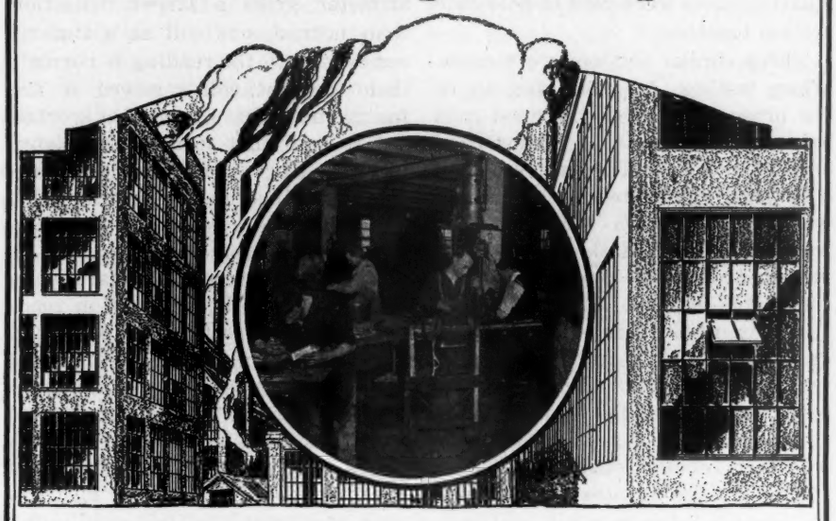
The first and last points of the curves were fixed from actual experiments from which the following rules were worked out: (1) The diameter of a ½-in. conduit must be at least 10 per cent larger than the diameter of the wire, or of the circumscribing circle of a group of wires, which may be safely pulled into it. (2) The diameter of a 6-in. conduit must be 20 per cent larger. (3) For lead-covered wires and cables, the percentages as defined under (1) and (2) must be, respectively, 20 and 30.

Intermediate combinations of the curve were tried out and found to be correct for practical purposes.

A definite rule of this character was devised by the author and first published as a requirement in the 1914 edition of the rules and regulations governing the installation of wires and apparatus for electric light, heat and power purposes in the District of Columbia. The rule as then expressed did not provide for using lead-sheathed cables.

Washington, D. C. W. S. JONES.

In the Repair Shop



This section is devoted to all sorts of electrical repair work, large and small. Special attention is given to tools found convenient at the shop bench and short cuts or improved methods. Articles on these subjects are always welcome.

Coil Winding Machine Made From Old Lathe

WE HAD in our shop an old lathe which we have recently changed into a winding machine for all kinds of coils. Armature, field, interpole, transformer and other coils have been wound on it. It is also equipped with a coil spreader at one end. This makes a convenient arrangement as the space between the winding head and the spreader can be used to hold the coils.

This is a 20-in. lathe, though, of course, the size is not important. The head of the lathe was turned around as shown in the accompanying picture. The face plate was then in position to clamp on the winding forms. For motor coils a Segur loop winder is fastened on the face plate. When winding coils on a core the lathe chuck holds the core.

The countershaft was mounted above the lathe head on four heavy stud bolts. These bolts rest on the head of the lathe and support the hangers of the countershaft. A loose belt connects the cone pulley of the countershaft with that of the head. This loose pulley is tightened by means of an idler which is controlled by a foot pedal. In this way the operator can start and stop while his hands are free for guiding the wire. The machine gives a range of speed of from 20 r.p.m. to 600 r.p.m. This will take care of most winding jobs.

A 5-hp. motor is mounted on the bed plate of the lathe as shown and is connected to the countershaft by a silent chain. A sheet-iron enclosure protects the chain and gears. The disconnecting switch is mounted on this just above the motor.

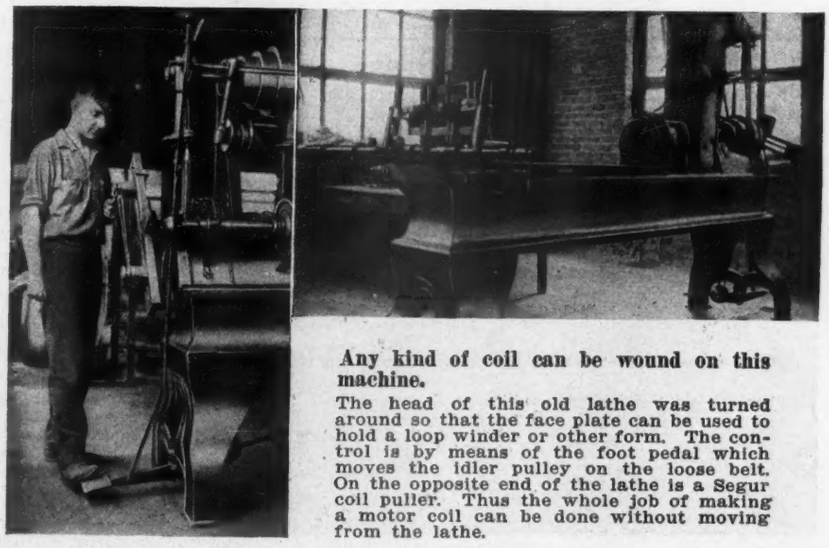
IVAN C. WEHNES.
Shop Foreman,
Welch Armature Co.,
Welch, W. Va.

A Rapid and Practical Method of Testing Field Coils for Short Circuits

A NUMBER of field coils recently came in for repair and a quick and simple method of testing for short circuits between turns was required. These coils were wound with forty turns of 1 1/16-in. by 3/64-in. bare copper strap wound flat with 0.010-in. asbestos paper between turns. The outer insulation on all the coils had to be removed. On some coils the insulation between turns was so old and brittle that rewinding was plainly necessary. Other coils looked good, and the problem was to determine whether they were good or short-circuited and to test the rewound coils for short circuits.

We had a growler used for testing large armatures and thought this could be utilized by building a laminated sheet-iron bridge across the "V" opening and putting the coil to be tested in this space. The photograph shows this standard Westinghouse portable armature-testing stand. The bridge is shown inside the field coil being tested. A portable ammeter is also shown connected in series with the two-pole single-throw knife switch that controls the primary circuit.

The principle of this test is that a good coil forms an open secondary, and an ammeter placed in series with the primary or exciting coil would show the magnetizing current only. With a short-circuited coil a current flows through the turns shorted, which increases the current flowing in the primary coil on the testing magnet. This causes the ammeter to give a higher reading and indicates a defective coil. In making the test, the bridge was first put across the opening, the switch was closed and the reading noted. Then the coils were put on and another reading taken. If this reading was higher than the other it meant that the coil was defective; if the read-



Any kind of coil can be wound on this machine.

The head of this old lathe was turned around so that the face plate can be used to hold a loop winder or other form. The control is by means of the foot pedal which moves the idler pulley on the loose belt. On the opposite end of the lathe is a Segur coil puller. Thus the whole job of making a motor coil can be done without moving from the lathe.

ing was the same, it showed that the coil was in good shape.

To determine whether the equipment was sensitive enough to detect a short between turns, a coil that on testing did not show any additional deflection on the ammeter scales, was again put on the tester after the insulation was removed. A loop of wire was used to short adjacent turns and the switch was closed. The ammeter gave a higher reading, which proved that the apparatus was suitable for the purpose intended. The drawing shows the dimensions of the assembled bridge laminations. One long and one short lamination were placed end-to-end as shown, each consecutive layer being reversed to stagger the joints. In building up the sections, two pieces of ⅛-in. brass wire were cut to the correct shape and dimensions. Then twelve ten-penny nails were driven into the bench around one piece of brass, as indicated by the black dots. The laminations were then built up inside these nails to the required thickness; then the second piece of brass was put on, the complete unit held together with two C-clamps and the three holes drilled as indicated. Three 5/16-in. bolts with paper insulating tubes were used to hold each section together.

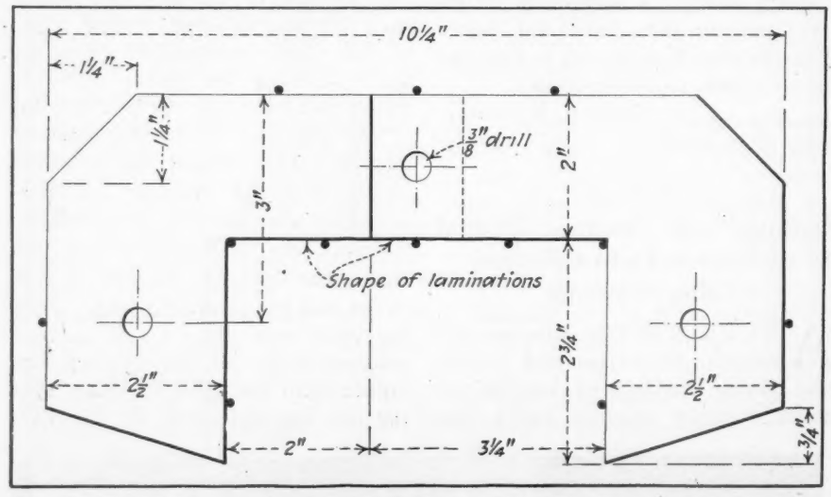
Three similar sections were made. When testing, only one section of the bridge was used, the good coils being put in one pile, and the shorted ones in another. Then after all the coils had been tested the insulation was removed from the coils that were defective and these coils were re-tested with the three sections of the bridge in place. This caused the short-circuited turns to heat up quickly, making it easy to locate the trouble. The short circuit in many cases was around the leads or a few turns from the top or bottom and was very readily repaired.

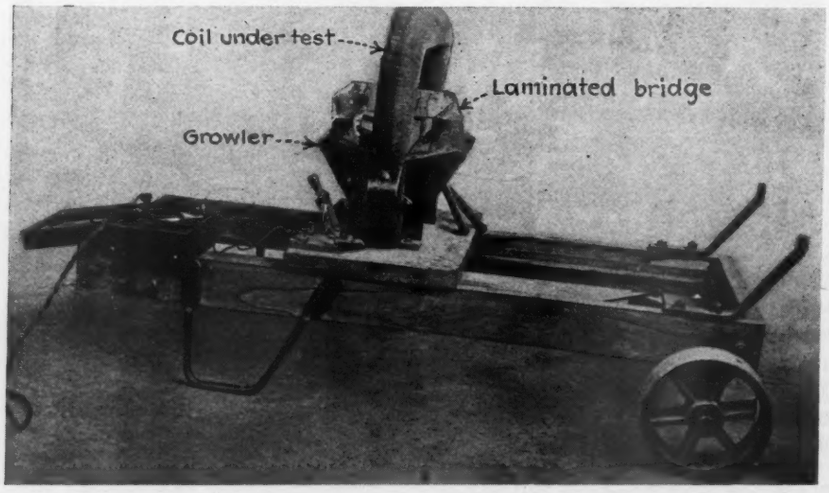
This bridge is also used to test armature coils for short circuits. One section is used and a number of coils are tested at a time. If the ammeter gives a larger deflection than normal, one coil at a time is removed until the reading is normal; then the last coil removed is the faulty one. This scheme has worked out so well that it is contemplated incorporating an ammeter as a permanent fixture on the growler with a double-pole, double-throw snap switch. The ammeter scale could be marked to show the standard one-, two-, and three-bridge section readings with the sections in place and secondary open. Then with a coil under test any reading past the mark corresponding to the sections in place would indicate a defective coil. A box placed at the foot of the apparatus to hold the bridge, makes a very convenient testing outfit at a slight expense.

A. C. ROE.
Detroit, Mich.

Short circuits in coils are quickly detected by this outfit.

Below is a coil set on the growler with a laminated iron bridge forming a closed magnetic circuit through the coil. A high reading of the ammeter indicates a short circuit in the coil. The drawing shows the shape of the laminations which form the bridge.





Changing a Cross-Over Coil to One Less Liable to Short Circuit

A MOTOR in which several coils had short circuited while in operation recently came into the shop. The coils were of the cross-over type, which is liable to short circuit at the points where the wires cross. The method of re-designing the coils so as to omit cross-overs should be of interest to other repairmen.

This was a 20-hp., 440-volt, three-phase, 60-cycle, ten-pole, 675 r.p.m. induction motor. The motor had 120 slots and 120 coils, partly closed slots, threaded-in, two-layer diamond-shape pulled coils wound in layers with ten turns of one No. 11 wire per coil, two wires wide by five high, pitch 1 and 10, connected series-delta with long jumpers (top-to-bottom). As this was a breakdown job, everything possible was done to save time.

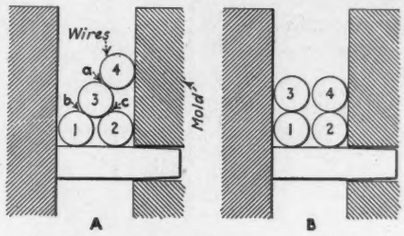
The coils for this motor were wound with one wire in hand and two wires wide, forming what is termed a "cross-over" coil. This type of coil requires more care and takes longer to wind than one wound with two wires in parallel, side by side. Also there is a greater danger of the coil winder pounding short circuits between turns. In fact the motor when received in the shop had six coils, which had burned out from time to time, cut out in different parts of the winding. Four of these short circuits were at the front end where the cross-overs occurred and two coils failed at the rear end at

the cross-overs. For this reason it was decided to eliminate the cross-overs if possible when rewinding.

The drawing at *A* explains how the insulation on the wire is weakened at the rear end of the cross-over coil when winding. The sketch shows the first four turns being wound between the mold end. The first two turns, 1 and 2, wind into place with ease, but the third turn has a tendency to fall down into the space between the wires as shown. Then when the fourth turn is put on, there is not enough space for it between the third turn and the mold. If the winder tries to pound 3 and 4 flat as shown at *B* there will be a crushing strain at points *a*, *b* and *c* which will short the turns.

To eliminate this hazard and to save time in making the coils, the winding was redesigned as follows: The motor has 120 coils, ten turns per coil, or 120÷3=40 coils per phase, and 40×10=400 turns per phase. As the motor was connected series-delta, the 400 turns developed 440 volts per phase, or 440÷400=1.1 volt per turn. Now what is required is a coil with two wires in parallel. With five turns of two No. 11 (2 wide by 5 high) connected series-star, the line voltage would have to be 5×40×1.1×1.73=380.6 volts. If the motor was connected in series-delta across 440 volts, the coils would be operating at 16 per cent overvoltage, which would be ruinous. It is possible, however, that the same kind of coil might be used if it had more turns. Now with a line voltage of 440 and a series-star connection the voltage per phase equals 440÷1.73 or 254 volts. Then the turns per phase to develop 254 volts equals 254÷1.1 or 231 and the turns per coil equals 231÷40 or 5.8 turns.

Now there are two ways of getting the effect of 0.8 of a turn; (1) by increasing the old coil pitch and hence the chord factor, or (2) by using six turns per coil and decreasing the coil pitch and chord factor. As there was ample room in the slots for the two extra turns (one in the bottom half and the other in the top half of the coil), the latter method was used. Six turns per coil equals $6 \times 40 \times 1.1 \times 1.73$ or 456.72 volts. Then by decreasing the coil pitch one slot, the chord factor is changed from 0.9239 to 0.866 which reduces the voltage per phase 6 per cent, approximately. In other words, with a pitch of 1 and 9 and six turns per coil the voltage will be 6×1.1×40×0.94×1.73=429, which is close enough to 440 volts. So the machine was wound with 120 coils of six turns of two No. 11 wires per coil, two wide by six high, pitch 1 and 9 connected series-star by means of long jumpers.



How the wires crowd in winding a cross-over coil.

The turns of the coil shown are likely to short circuit at the cross-overs. The article tells how such a coil was replaced by one which had no cross-over.

Making the change in the coil saved at least eight hours of the rewinding time and made a job that would stand up. A. C. ROE.

Detroit, Mich.

Preparation Necessary When Soldering Electrical Equipment

SOLDERING may be regarded as a chemical operation carried out by heat. The parts must be clean and covered with some substance, known as a flux, which will dissolve the oxides that form on the metal by the action of the air, so that the solder can get into chemical contact with the clean metal.

Soldering can be done by using an "iron" to transmit heat to the joint, or by heating the joint by dipping it in melted solder, or by blowing a flame on it. Soldering irons are made in a variety of sizes and shapes, depending on the character of the work.

Common solder is known as "half and half," as it is composed of equal parts of tin and lead. This grade is used for most work and has the characteristic of softening at a fairly low temperature and remaining mushy until considerably hotter, when it becomes very thin. The other kind of solder used in electrical work is called hard or AC solder. It has more tin in it, takes more heat to soften it and gets very thin almost as soon as it softens. It is used for soldering squirrel-cage rotors and stators.

Burnley's soldering paste is a good flux for soldering copper. When it is used on joints which are to be taped, they should be washed off with gasoline after soldering, to remove any excess of flux. Another flux is made of rosin dissolved in benzine or rosin alone, or even good rosin varnish can be used. Acid soldering solution or salts should never be used for electrical connections, as the residue will absorb moisture and cause corrosion, which will ruin the insulation. The following formula for a non-corrosive soldering fluid is taken from the National Electrical Code: Saturated solution of zinc chloride, 5 parts; alcohol, 4 parts; glycerine 1 part.

In soldering joints in windings, an iron is used except in the case of a. c. stators. where the end connections can sometimes be sweated by dipping. This is done by turning the stator on its side, connections down, and wrapping each joint in very thin asbestos paper applied wet and allowed to dry, thus sticking it to the copper. Then a narrow, deep ladle full of hot solder is brought up so that the joint dips in it, heats up thoroughly and fills with solder. The ladle is then removed and wire solder is fed in to make sure that the joint is full. The asbestos paper should be removed before taping up.

Soldering commutator tails is an important job, inasmuch as a poor joint is sure to cause trouble in the shape of black spots and overheating. As it is impossible to get at the side, all of the heat must be transmitted from the iron to the joint through a small area at the top. The joints must be perfectly clean and wedges driven in to bring the copper of the tails as close as possible to the leads. The irons must be well tinned by rubbing, while hot, on sal ammoniac crystals and solder. Time must be given for the joint to heat up thoroughly, so that the solder will run in all the way and not merely around the edges. To avoid delay in waiting for hot irons, a torch flame may be held on the iron as long as it works satisfactorily. This is practically as good as a gas iron. It requires two men; one to hold the iron and feed solder,and another to hold the torch. For small tails a soldering iron tip for the torch works well. Electric irons are not so good for this work, as they do not stay hot enough. It is safe to say that success in soldering depends 90 per cent on getting joints ready and clean and on having good tools, properly heated. JAMES DIXON.

Cleveland, Ohio

Handling Materials

Better ways to transport and handle raw and finished parts in and around the works will be discussed in this section.

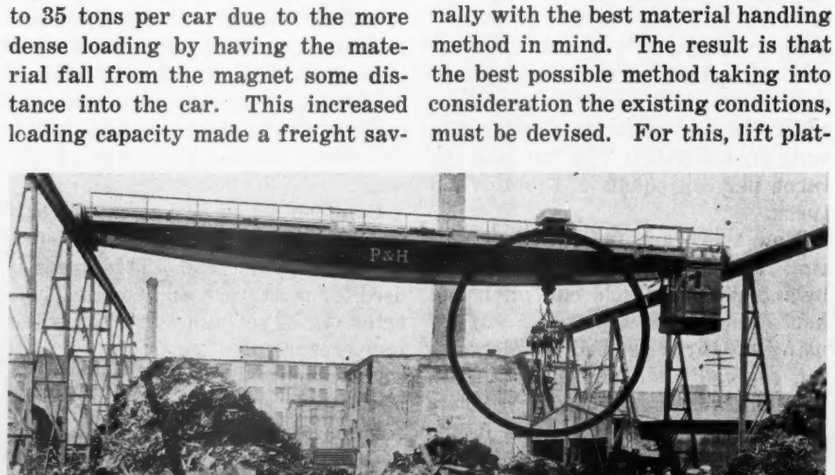
Traveling Crane and Magnet for Handling Metal Scrap Which Paid Their Installation Cost in Less Than a Year

IN ESTIMATING the amount of saving which results from the installation of material handling equipment, incidental savings other than reduced labor costs are too often neglected. This is well shown in the crane and magnet installation for handling scrap steel at the Silver Iron and Steel Company, Racine, Wis. Here, after all the other reductions in cost had been figured up, an additional saving was found of over $1,000 per year due to the elimination of the up-keep of the wheelbarrows, shovels, forks and other hand tools used by the 40 men in handling the scrap. This saving alone would represent an earning of 6 per cent on an investment of over $16,000.

Before putting in this installation, 40 men who were used regularly in the yards were able to load and unload a total of only 40 cars per month. A large portion of their time was taken up in building runways for wheelbarrows, lowering gates of the gondolas and similar work. In addition, they were only able to load about 16 tons of lightweight steel scrap into a car because the steel was dumped in such small quantities that it did not pack well.

After installing the Pawling & Harnischfeger 7½-ton crane shown in the accompanying illustration, the capacity of the cars was increased to 35 tons per car due to the more dense loading by having the material fall from the magnet some distance into the car. This increased loading capacity made a freight saving of $30 per car on shipments between Racine, Wis., and Middleton, Ohio. An additional saving was made in that no wheelbarrow runways were necessary. The output was increased over 100 per cent, with a 50 per cent reduction in men and a corresponding saving in wages. Individual pieces up to 15 tons have been carried to the skull cracker.

The operating cost for the crane and magnet averages about $180 per month or $6 per 8-hr. day of continuous operation. This is based on a rate of $0.0175 per kw.-hr. It has been estimated that the total savings have covered the entire installation cost in less than 12 months. This overhead traveling crane was manufactured by Pawling & Harnischfeger, Milwaukee, Wis. It is of 7½ tons capacity, has a span of 60 ft., lift of 30 ft. and a hoisting speed of 35 to 70 ft. per min. with a 30-hp. motor. A bridge speed of 300 to 350 ft. per min. on the 220-ft. runway is obtained with a 20-hp. motor. A 6-hp. motor gives a trolley speed of 150 to 200 ft. per minute. All motors are operated on 220-volt direct current. The 52-in. circular magnet was made by the Cutler-Hammer Company, Milwaukee, Wis.

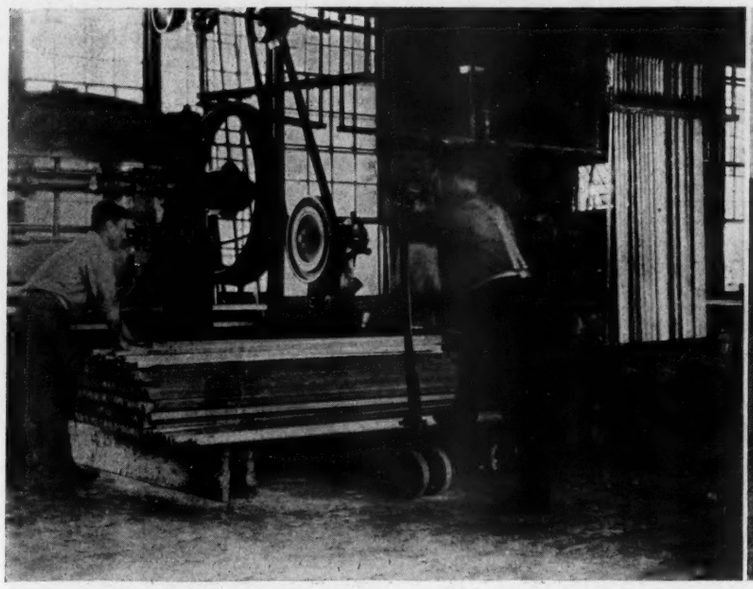


This 52-in. Cutler-Hammer magnet is lifting 1,700 lbs. of rail anchor scrap at one "bite."

The most important savings made by this installation were in decreasing by one-half the number of men required and at the same time doubling the amount of material handled in a month. Incidentally, large savings were made through eliminating the necessity of using wheelbarrows and other hand tools which alone amounted to over $1,000 per year. A further saving was made in that as the wheelbarrows were no longer used, it was not necessary to build runways to the cars. A freight saving, which in some cases amounted to $30 per car, also helped add to the total saving.

Handling Steel Posts on a Lift Truck With Stationary Skid Supports

COMPARATIVELY few industrial plants are laid out originally with the best material handling method in mind. The result is that the best possible method taking into consideration the existing conditions, must be devised. For this, lift plat-



Four or five tons of steel posts are handled to and from the punch press and to the crane by this truck. In this case skid legs are used without a platform; the load is lifted directly by the platform of the truck.

form trucks, either hand or electrically operated, often show large savings. One such case is in the handling of steel fence posts at the Chicago Heights, Ill., plant of the Calumet Steel Company. The two accompanying illustrations show how these posts are now handled from the punch press to the yard crane where they are carried either to stock or for shipment. Here the posts are piled crossways on stationary 2-in. by 10-in. planks built on edge to form skid supports, as shown. As the planks are in pairs they are not easily tipped over, even though a platform is not used. A lift truck is run under the pile of posts, elevated and carried to another pair of skids just outside the door of the plant, where they can be picked up by a crane, as shown in the second illustration.

Before this installation was put in the steel posts were piled on the floor, picked up, punched, and again thrown on the floor to be picked up later. All of this unnecessary rehandling was eliminated by the use of the truck as now the punch-press operator picks up the post from one pile, punches it and a boy helper places it on another pair of skids to be moved.

This is a specially built Steubing elevating-platform truck for heavy duty. Ordinarily, four or five tons of steel posts are handled at a time by two men with this truck. This, however, is only one of the tasks as many other similar duties are also simplified by the use of the truck which is made by the Steubing Company, Cincinnati, Ohio.

Getting Five Men To Do the Material Handling of an Eight-Man Gang

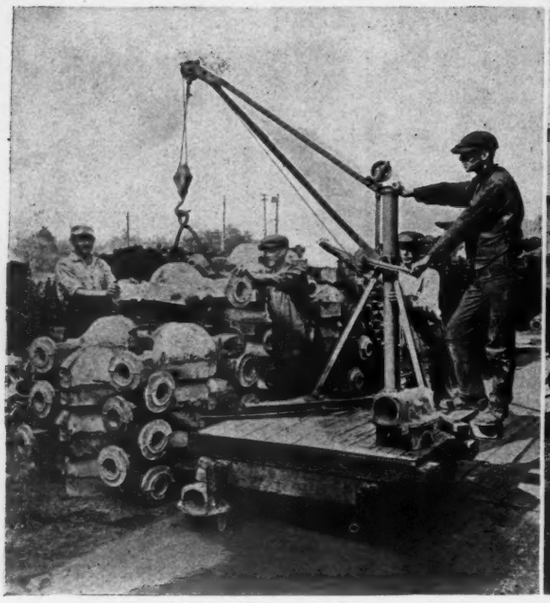
WHERE IT is not practicable to measure the work done, the plan adopted by the foreman who had charge of the eight truckers in one plant can be used. He noticed that important truck loads were not being moved as fast as necessary, that trucks became congested about the elevator and that the truckers rode up and down on the elevator with their loads. When one of the men quit, the foreman called the other men, including the elevator operator, together and offered them the extra man's pay if they would do all the work. He showed them how the time was wasted riding up and down on, or waiting for the elevator, how they could leave a truck at the elevator and let the operator push it on and off at the proper floor and bring other truckloads down while the men were out trucking instead of waiting at the elevator, and many other methods of saving time.

The men finally agreed to try out the foreman's suggestion. Within a week they had cleaned up all the trucking and approached the foreman with the suggestion that he discharge one of the men who shirked and let the six men do the work. He agreed and when, a short time later, another man in the gang quit, allowed the five men to handle the job on the agreement that if they fell behind they must clean up all the trucking before they left the plant, and without overtime. It keeps them moving, but it is only occasionally that they work even five minutes overtime. The men are satisfied with the three extra men's pay divided among the five and never ask for another man on the gang, even with considerable fluctuation in the daily output.

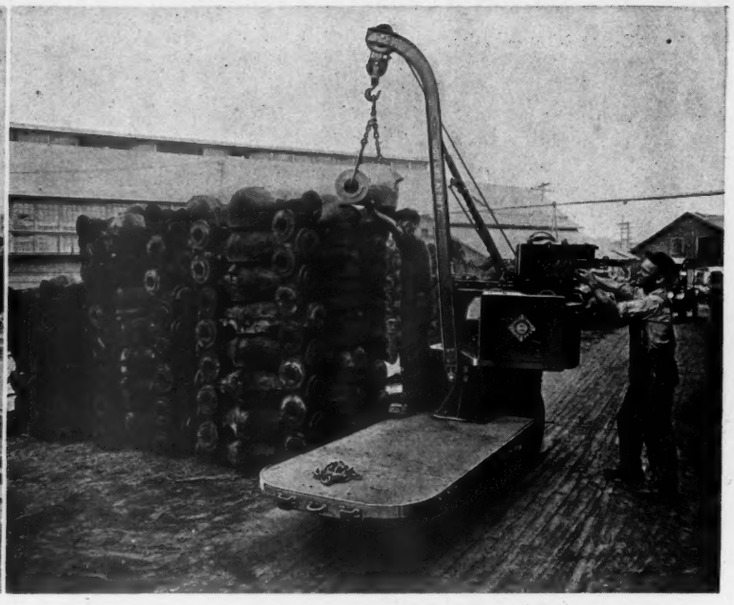
Piling Axle Housings Twice as High with Half the Work

PILING heavy material is one job which can generally be done much more easily and at less cost by some mechanical means than by hand. Even then, frequently a better means of handling can be obtained which again cuts the cost by speeding up the work and requiring fewer men. Such, at least, was the experience in handling heavy axle housings at the Wilkes-Barre, Pa., plant of the Sheldon Axle & Spring Company. Here a hand-power hoist was used as shown in the left of the two illustrations on the next page, to pile the axle housings in the form of a hollow square. With the hand equipment two men were required to operate the hoist while two others stacked. Even then, with hard work it was possible to pile only four high.

Since an Elwell-Parker electric lift truck with a crane attachment, as shown in the illustration at the right, was installed, two men, one to operate the electric hoist and the other to



Four men had hard work with this arrangement.
This hand-operated crane required two men to crank up the load and two others to swing and pull the heavy axle housings into position on the pile. Even then it was possible to pile only 4 housings high, or 16 to a pile.



Now two men pile housings twice as high with much less work by using a storage battery crane truck.
In addition to getting twice the capacity in yard storage, the two men do the work in less than half the time. The incoming housings are loaded onto platforms by the crane and carried to the yard storage space by electric lift platform trucks (not shown here) and then piled as shown.

steady the axle housing and guide it into position, can handle and pile the housings in less than half the time. In addition, they can pile the axle housings eight high and so store the same number of housings in half the space or double the yard capacity, which is an important item when yard space is limited. Also, as fewer men and less hand-handling are involved, the possibility of accidents to the men is greatly decreased.

With this storage-battery crane truck heavy pieces like this can be lifted on the platform of the truck, carried to storage and lifted into place without calling out a gang of men if even only a few pieces are to be handled. In this work the heavy housings are piled on a lift truck platform and carried to the yard storage by a storage-battery lift-platform truck. After the pile of housings is loaded onto the platforms the crane truck goes to the storage yard and piles them.

In operating the hoist, which is controlled by a separate motor from that driving the truck, the storage battery box is so placed as to be supported on ball bearings and swing with the crane and serves as a counterweight to balance the load. The boom of the crane can be extended to almost vertical and can be raised or extended under load. It has a hoisting capacity of 3,000 lbs. at 6 ft. outreach by using outriggers, or 2,000 lbs. at 4 ft. without outriggers, at a hoisting speed of 10 ft. per min. The platform capacity is 3,000 lbs., which it can carry at from 3½ to 5 m.p.h. or from 300 to 400 ft. per min. The truck was manufactured by the Elwell-Parker Electric Company, Cleveland, Ohio.

Speeding Up the Unloading of Cars With a Lift Truck

A PLANT which is not on a private-switch track but receives and ships in carload lots may be able to reduce the cost of handling between car and plant by the use of lift trucks, as was done at one specialty printing plant. Here large amounts of paper stock are received and hauled to the plant. Formerly the boxes in which the paper was shipped were pulled out of the car, piled on a motor truck, hauled to the plant, unloaded onto hand trucks and taken to the storage space where they were again handled when piled. During this process each package was handled by hand at least three or four times.

Since lift trucks and skid platforms have been installed only one handling has been necessary. Now a lift truck and several empty skids are put on the motor truck and taken to the car. A platform is placed on the truck as it is backed up to the car door and enough of the boxes of paper unloaded to put the next platform inside the car. As each platform is loaded it is hauled into the motor truck by the lift truck and deposited as a unit. When the motor truck is loaded it goes directly to the plant and the skids with their loads are taken off with another lift truck and hauled to storage. A tiering machine is used to pile one loaded skid on top of another and so double the storage capacity. During all this time the box of paper is not lifted by hand except when piling on the platform.

While the truck is taking its load to the plant the men are loading other platforms with boxes and hauling them to the car door. Thus when the motor truck gets back, and it takes only a few minutes to unload, another load is ready. In this way the motor truck, after the first load, has no waiting. In loading cars the process is practically in a reverse order. The lift truck is used to place the loaded skids in the car, thus releasing the motor truck, and then haul the skids to the end of the car where the packages are piled. The men gradually work back to the door and the motor truck is again required to assist in closing up cars. This plan eliminates practically all carrying, as the platform can be hauled almost anywhere. It has doubled the capacity of the motor truck and the rate at which cars are loaded or unloaded. The same plan can be used where cars are spotted at the receiving platform.

Wound Rotor Connections

(*Continued from page* 539)

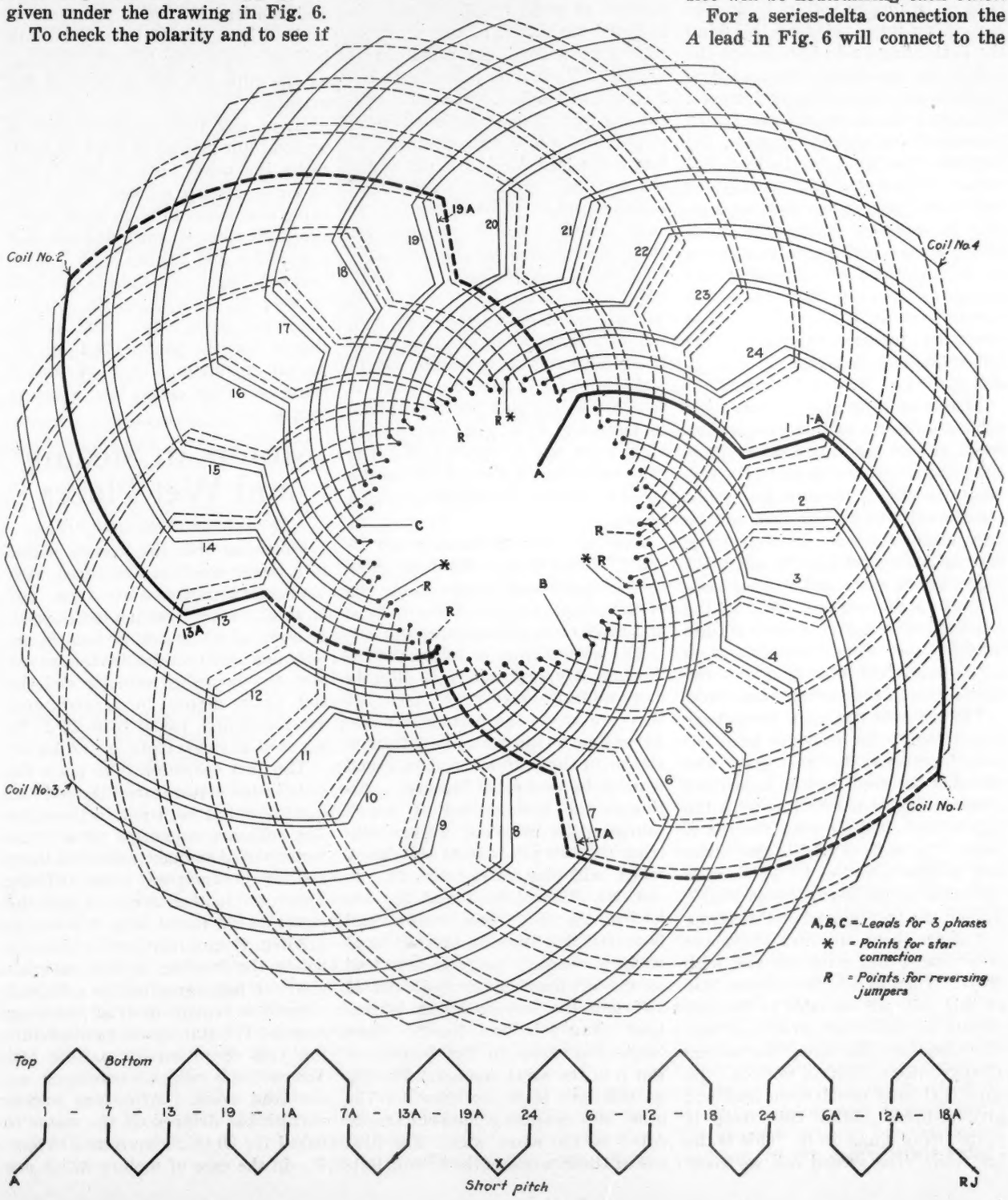
tions 2, 4 and 6, while the reversing jumpers will always connect together the bottom of the last slots in sections 1 and 4, 2 and 5, and 3 and 6. After making a diagram of this kind, apply the arrows and check for polarity as was done in Fig. 3. The data required when stripping is given under the drawing in Fig. 6.

To check the polarity and to see if the top and bottom halves of any of the coils are neutralizing one another, set down the number of slots in a horizontal row, as done in Fig. 3. This is also shown in the lower right-hand part of Fig. 6. If this is done with the diagram in Fig. 6 it will be seen that there will be two arrows for slot No. 15, one of them pointing up and the other one down. This means that the currents in the upper and lower parts of this slot will be neutralizing each other.

For a series-delta connection the *A* lead in Fig. 6 will connect to the

Fig. 7—Connections for a strap-wound rotor using a winding with four coil sides per slot.

This is a strap-wound rotor connected series-star for four poles three-phase. There are 24 slots and 48 coils of one turn each with four conductors per slot. The winding pitch is 1 and 13 while the front pitch and back pitch each are 1 and 7. The leads *A*, *B* and *C* connect to the right-hand top straps in slots 1, 9 and 17, respectively. The star connections go to the right-hand top straps in slots 15, 23 and 7. The reversing jumpers connect the bottom left-hand straps in slots 2 and 8, in slots 10 and 16, and in slots 18 and 24.



top of slots 1 and 9. The *B* lead will connect to the top of slots 15 and 7 and the *C* lead to the top of slots 4 and 12. This means that a lead will be connected to the top of the first slots of the following pairs of sections: 1 and 6; 2 and 3; 4 and 5.

Connecting Up Rotors Wound With Strap Copper

On a rotor wound with strap copper coils, especially if there are several conductors in a slot, it may be hard to locate the bottom leads. In connecting up a rotor of this kind the first thing to do is to locate the points for the leads, the star connections and the reversing jumpers. The diagrams of course are drawn as already explained. Suppose, for example, that the rotor in Fig. 7 is taken. This rotor has twenty-four slots with four conductors per slot, and 48 one-turn coils. The leads attach to the right-hand top straps in slots 1, 9 and 17. The star connection is to the right-hand top straps in slots 7, 15 and 13. The reversing jumpers connect to the left-hand bottom straps in slots 2 and 8, 10 and 16, and 18 and 24.

The chief difficulty in connecting such a winding is that the bottom leads cannot be followed to their slots. However, by means of a test lamp placed on the top lead of a certain coil the bottom lead can be very easily located. In Fig. 7 the bottom leads have been brought out to the inside circle and the top leads to the outside circle. This is the same relative position as they occupy on the rotor. The first thing to do is to locate the first lead and the first series of coils around the rotor.

The rotor is put on a horse near a test lamp. If the slots have not been numbered by the man who stripped the rotor, a top right-hand strap is picked out in line with the lug on the collector ring for the *A* lead. The slot in which this strap lies is called slot No. 1. This coil is indicated by the heavy line in Fig. 7. To find the bottom lead of this strap, lift it up about one inch above the other leads, and mark the slot with chalk. Then to find the bottom lead of this coil, put one side of the test circuit to this first strap and run the other test lead along the bottom straps until a light is noticed. Be sure that only one bottom lead will give a light. After this strap is found, hang a clip on it. This is the first coil. The second coil we know lies in the top of slot No. 13. We found this by adding the winding pitch which was 12 or a pitch of 1 and 13. Therefore, taking the right-hand top strap of slot 13, we bend it over the bottom strap just found with the test lamp and clip the two straps together. This connects coil No. 1 to coil No. 2. Then keeping the test leads on strap No. 1, the bottom of coil No. 2 may be found with the other test lead. The bottom of No. 2 should be a little to the left of strap No. 1. When this is found the course of one series of coils once around the armature is known. The bottom lead of coil No. 2 should be marked. Instead of continuing with the connections for the *A* phase, the next thing to do is to locate the lead for the *B* phase and connect the first two coils of this phase together. This is done in the same way as it was for the *A* phase. It is known from the data that the lead for the *B* phase is the right-hand strap in the top of slot No. 9. The bottom of this coil is found with the test lamp and is connected to the right-hand strap in the top of slot No. 21. After the series is found, then the lead for the *C* phase is located. This lead lies in the right-hand side of slot No. 17. The first two coils in this phase are located as already described for the *A* phase.

Next the star connections are located. According to the data, these are the right-hand straps in the top of slots 7, 15 and 23. Lift up these and mark them with a paper tag.

The next step is to locate the reversing jumpers, which is slightly more difficult owing to the fact that they are all in the bottom of slots. According to the data, the left-hand straps in the bottom of slots 2 and 8 must be connected together. Although the bottom lead of slot 2 cannot easily be found, we can subtract the coil pitch from slot No. 2 which will give us slot No. 21. In slot No. 21 will be found the top lead of the coil whose bottom lead is in slot 2. Then as the left-hand strap is wanted, put one test lead on the left-hand top strap in slot 21 and find the corresponding bottom lead. Tag this lead No. 2. Then locate the strap in the bottom of slot 8 in the same manner. The top of this coil is in slot No. 2. The other two reversing jumpers are located in the same way. The first one of these connects the bottom left-hand strap in slots 10 and 16. The other one connects the bottom left-hand straps in slots 18 and 24.

After these different straps have been identified it is easy to connect the leads up in regular order. Start at the finish of coil 2, which was found as described. This lead is just to the left of the *A* lead and is a bottom lead. Connect the top lead just to the left of the *A* lead to this bottom lead in coil No. 2. In this way proceed around the rotor until each top lead is clipped to a bottom lead. There should be one bottom lead corresponding to each top lead, as the clips are put on around the armature.

If, at any time, a motor with a wound rotor refuses to start its load, make the usual tests to see if the motor is getting voltage. If everything else seems to be in good order, check the rotor by removing one star connection and testing with a lamp between rings. If a light is obtained between all three rings, the rotor is connected incorrectly. The indication is that the phases are interconnected, forming a low resistance rotor winding with low starting torque.

Motors in Steamy and Wet Places

(*Continued from page* 518)

Following this the loop is pulled in a Segur machine and taped with ¾-in. varnished cambric tape, .007 in. thick, rather less than half-lapped. A layer of white cotton tape ¾ in. wide and .007 in. thick is then wound over the varnished cambric and the coil again dipped in varnish and, after dripping, baked from 20 to 24 hours at a temperature of 212 deg. F.

The next operation is to place the coils in the stator, after fiberoid slot insulation has been put in the slots. The coils are connected up and the motor tested to make sure that there are no grounds or other defects. The rotor is then removed and the stator baked for at least 8 hours at 212 deg. F. and immersed while still hot in the Sterling or Ajax varnish used for impregnating the coils and allowed to remain until all bubbling ceases. The stators are handled during this operation by a Yale and Towne hoist which travels on an overhead track. After the excess varnish has dripped off the stator is baked for 20 to 24 hours at 212 deg. F. In the case of motors which are

exposed to exceptionally severe conditions, the stator is again dipped in the varnish and baked. In any event after the final impregnation the stator is given a spray coat of Sherwin-Williams black spirit varnish. The rotor is then put in and the motor fitted with a pulley and sent to reserve stock. About thirty motors of various sizes are kept in stock.

In the case of partly-closed-slot motors, which are usually less than 15 hp. in size, the repair procedure is somewhat different. The loops are not varnished, but are placed in the slots, which are insulated with fiberoid slot insulation, and taped in place with cotton tape. The stator is then immersed in insulating varnish until all bubbling ceases and after the excess varnish has been allowed to drain off, the stator is baked for 24 hours at 212 deg. F.

With a few exceptions all machines and line shafts are belt-driven and so in order to avoid confusion and delay in changing motors, and at the same time obviate the necessity of keeping a large stock of spare motors on hand, belt speeds have been standardized. A speed of 9,600 feet per minute has been selected as most suitable and every spare motor before being sent to stock is provided with a pulley of the proper size to give this belt speed, regardless of the speed of the motor itself. Then when an emergency call comes in for a 20-hp. motor, say, any make of motor of this size in stock can be selected and installed, with the assurance that it will drive any machine or lineshaft at the proper speed.

Rewound Motors Give About Twice the Service of New Motors

The exact value or worth of the treatment described above, which is given to the coils of rewound motors, can hardly be expressed in figures. The same thing is true of the average life of the coils of a new motor. The great majority of the motors in this plant operate under conditions which are very bad, judged by ordinary standards, but there is enough variation in the kind and severity of the conditions to make direct comparison difficult. In some locations the best designs of standard motors have failed within two weeks. In other places they may not give trouble for three or four years.

The motor operation records which have been kept for many years show, however, that at a very conservative estimate this treatment will add 100 per cent to the life of the coils. In other words, a rewound motor with the coils treated as described, will stand up approximately twice as long as would a new, standard motor. Last year approximately 125 motors of all sizes were rewound and treated in the repair shop.

Spraying a coat of black spirit varnish on a rewound stator.

After the final dipping and baking operations, a finishing coat of Sherwin-Williams black spirit varnish is sprayed on. The motor is then assembled and the proper size pulley put on to give the standard belt speed of 9,600 feet per minute, after which the motor is sent to the motor stockroom.

As might be expected a good deal of trouble is also encountered with compensators, inasmuch as these are exposed to substantially the same conditions as the motors. In this instance the trouble is both mechanical, corrosion and rusting of the cases and iron parts, and electrical, in the way of shorted or grounded coils. Frequent painting and replacement of badly corroded iron parts are the remedies for most of the mechanical troubles, while coils which become defective in service are replaced by new coils, wound in the repair shop.

As in the case of stator coils, thorough impregnation with a good insulating varnish is relied upon to resist the effects of dampness. Consequently, when the coils are being wound each layer is well coated with Sterling or Ajax clear insulating varnish, applied with a brush. After the coils are finished they are baked for 10 hours at 212 deg. F., dipped in the varnish and allowed to remain until all bubbling ceases. The excess varnish is then removed by dripping and the coils again baked as before.

Lighting in Woodworking Plants

(*Continued from page* 514)

Filling and varnishing.—As a final process a large portion of the products of many woodworking plants are varnished, stained or otherwise treated. These operations must be performed with care and hence it is necessary that the workmen be able to see clearly what they are doing. For most purposes a system of general illumination averaging 5 ft.-candles in intensity is entirely satisfactory. For especially fine work, a closer spacing of the lighting system may be provided, as seen in *C* of Fig. 2.

In general there is a number of principles which should be observed for any system of illumination. The wiring should be laid out in as simple a manner as possible. The lighting units should be systematically arranged and the switches so located that the plant may be lighted in sections. Frequently it is desirable to carry on work in only one part of a room and it should then not be necessary to burn all of the lights. The lighting units should be so hung and spaced that shadows are not cast on the work by the workmen or by overhanging objects. As few sizes of lamps as possible should be used. Frequently lamps are interchanged and when several sizes are in use a low-wattage lamp may be accidentally replaced by a larger one or vice versa, thus spoiling the uniformity of the illumination. As a supply proposition it is much easier to provide for a few sizes of lamps than to carry a large variety.

Dirt and dust accumulations on lamps and reflectors are one of the greatest factors in reducing the efficiency of any lighting system and unless provision is made for cleaning at frequent intervals the finest kind of lighting system will be inefficient. The lamps sometimes become blackened toward the end of their rated

life even though they have not burned out and when this happens they should be replaced. The amount of light given off by such a lamp is considerably below normal, while the energy consumed is nearly the same.

Closely related to good lighting is the color of walls and ceilings. It is highly desirable to finish pillars, walls and ceilings in a light color, as this will assist materially in the illumination. Furthermore it is important to refinish the walls and ceilings frequently enough to keep them in good order.

NOTE.—If the reader wishes to follow this subject in other writings he should consult the following articles: "Industrial Illumination" (Lumber Mills), F. E. Murphy, Journal of Electricity, June 11, 1918; "Improved Lighting of Woodworking Plants," F. H. Bernhard, Electrical Review, Sept. 15, 1918; "Lighting the Factory Effectively," Lew Monous, The Woodworker, December, 1920; "Selecting Illumination for the Industrial Plant," J. J. McLaughlin, Journal of Electricity, July 15, 1921.—EDITOR.

Trade Literature
You Should Know About

Adapti Company, East Seventy-Second Street and Kinsman Road, Cleveland, Ohio—An interesting house organ called "The Adaptibox" will be issued regularly and distributed to those who wish to be put on the mailing list.

Century Wood Preserving Company, Century Building, Pittsburgh, Pa.—Bulletin No. 24 describes the method of treating and handling ties and other timbers, including wood blocks for industrial plants. A table is included which shows the industrial uses of treated timbers.

Titan Manufacturing Company, 140 South Dearborn Street, Chicago, Ill.—Recent literature describes the new Titan portable electric drill with a capacity to 5/16 in. in steel and to ⅜ in. in other metal and wood. It weighs 54 lb. with an over-all length of 11½ in. and is provided with a special Westinghouse 110-volt, 60-cycle universal motor and a Cutler-Hammer switch.

The Cutler-Hammer Manufacturing Company, Milwaukee, Wis.—Publication 2,030 describes the operation and illustrates the use of Cutler-Hammer magnetic clutches in direct connecting motors to machines and driving shafts. Ease of operation, smooth acceleration and low maintenance are three of the features claimed for this clutch.

B. F. Sturtevant Company, Hyde Park, Boston, Mass.—Sturtevant "Unit Dryers," which consist of a motor-driven fan, the air from which passes over heater coils and is then discharged into a cabinet, are described in Bulletin No. 299. These dryers are made from the size which may be set on a bench to those into which may be wheeled a number of trucks holding several trays of the material to be dried.

Condit Electrical Manufacturing Company, South Boston, Mass.—Industrial Handbook No. 5,000 describes the air circuit breakers, oil switches and circuit breakers, oil motor starters and service switches for small industrial apparatus of 750 volts or less, either direct or alternating current, which are designed to conform to the requirements of the Safety Commissions and Industrial Underwriters. In addition to a number of handy tables the handbook contains the Underwriters motor rules.

Bodine Electric Company, Ohio Street and Oakley Boulevard, Chicago, Ill.—A 32-page booklet on the testing and selection of fractional horsepower motors contains, in addition, illustrations and comments upon 50 different applications of small motors. A copy will be sent upon request.

Square D Company, Detroit, Mich.—Bulletin No. 30 describes the 80,000 series of Square D industrial switches with positive quick make and quick break and cover control in both fused and unfused types.

California Tanning Company, 1905-9 Shenandoch Avenue, St. Louis, Mo.—A circular quotes prices on lace leather and cut lacing for belts. In addition, quotations are included on other leather goods such as aprons of muleskin and cowhide, with and without bibs.

The Electric Controller & Manufacturing Company, 2700 East 79th Street, Cleveland, Ohio—Recent announcements cover a new squirrel-cage induction motor which, it is claimed, contains new ideas in motor design, both from a mechanical standpoint and from the standpoint of efficiency, power factor and torque. The stator frame is cast around the stator laminations, thus insuring perfect rigidity and alignment. The frame is of the skeleton type, so that the major portion of the stator laminations are exposed to the air. Fan blades are used on only a few of the 900 r.p.m. motors. Most of the cooling of the 1,200 and 1,800 r.p.m. motors is done by direct contact of the laminations with the air. Stator windings are impregnated twice and coils are form wound for open-slot construction.

Frisz Manufacturing Company, Inc., Indianapolis, Ind.—"The puller with the straight line pull," which is made in four sizes, to remove gears, pulleys, truck wheels, and so on, of 5, 6, 18 and 30 in. maximum diameter, is covered in a small folder.

Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa.—Recent announcement is made of a new transformer load indicator for determining the load on distribution transformers, and for many other practical purposes. The most important use for this device is to indicate when a transformer is overloaded, but it can also be utilized to determine whether transformers operating in a bank or in parallel are properly dividing the load. Underloading can also be detected by setting the indicator to trip at a low temperature, failure to trip at this low temperaure being an indication that the transformer is underloaded.

The Akron Sheet Metal Company, 103 North Main Street, Akron, Ohio—The Acme oil drip pans and hangers to catch oil from overhead shaft hangers are described in a small folder. This equipment is easily attached or removed for emptying and holds the drip pan level.

Buffalo Forge Company, Buffalo, N. Y.—Catalog No. 410-A describes the types and application of Buffalo exhaust fans for the removal of shavings, sawdust, and emery dust, for the elevation of cotton, wool and grains, for the removal of smoke and fumes, and for allied uses. In addition to details of construction and tables of capacity and performance data, this catalog contains considerable practical information on determining pipe sizes, friction loss, hood construction and pipe layout, the determination of the friction loss, the proper operating speed, and the power required for an exhaust system.

Sprague Electric Works of the General Electric Company, 427 West 34th Street, New York City—The construction and operation of the Sprague electric hoists Type WX, worm drive, is illustrated in bulletin No. 68,912.

Roller-Smith Company, 233 Broadway, New York City—Bulletin No. 250 covers the types LGD and KGD portable direct-current galvanometer for electrical measurements involving the use of a bridge network.

Z. & H. Manufacturing Company, 1224 North Parkside Avenue, Chicago, Ill.—A recent folder gives specifications and dimensions of its latest improved type of externally operated, single- and double-throw switches for alternating and direct current.

B. F. Sturtevant Company, Hyde Park, Boston, Mass.—Bulletin No. 283 describes and illustrates the construction of Sturtevant "Autoforce" natural draft ventilators.